

ECONOMIC CROPS
VOLUME V

CHERRIES AND
CHERRY PRODUCTS

**CHERRIES AND
CHERRY PRODUCTS**

ECONOMIC CROPS

*A series of monographs on the chemistry, physiology,
and technology of food and food products*

Z. I. KERTESZ, Editor

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CHERRIES AND CHERRY PRODUCTS

By Roy E. Marshall



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HERRIES AND HERRY PRODUCTS

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Michigan State College

East Lansing, Michigan

1954

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EDITOR'S INTRODUCTION

Although in this country cherries were never so popular on the market place as in Europe, a few generations ago cherry trees could be found over most of the United States, in orchards and gardens and along the roadside. The manner of growing cherries has changed since, as has almost everything else.

The rapid increase in the use of processed foods resulted in profound changes in the patterns of production as well as of consumption. With increasing demand for large lots of cherries identical in characteristics and maturity, cherry growing has been concentrated in the few districts most suitable for this crop. The early approach of canning "the surplus available" is surely a long cry from today's intense large-scale production of canned and frozen cherries. The widespread consumption of processed foods—right up to the frozen cherry pie of recent days—has had a profound effect on our mode of living and has led to a marked improvement in our diet.

Like most developments, this rapid evolution of food processing and the consequent concentration and intensification of agricultural production also brought on many serious problems. For most crops, protection against plant disease and insects became a major problem. Operations involving large quantities of highly sensitive and perishable fruit demanded the development of new methods of packaging, handling, and transport. Cherries had their share of the problems which had to be solved one by one to allow the evolution of the impressive cherry industry of today.

The author of the present volume, the fifth of our series of monographs on "Economic Crops," has been active in the heart of the cherry country for many years. He has had intimate contact with both the horticultural and the processing aspects of the cherry industry. We hope that this book will be of aid to cherry growers, processors, and all others who participate in the production of fresh or processed cherries, and in the manufacture of cherry products.

I wish to thank Dr. Marshall for his patient cooperation in keeping his book within the scope and physical limitations of our series.

Z. I. KERTESZ

Geneva, New York



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PREFACE

The foremost objective in preparing the manuscript for this book has been to assemble a digest of the existing data and literature pertaining to the cherry industry in North America. Special emphasis is directed to the importance of the cherry, the morphological, physiological, and biochemical changes occurring in the fruit, both before and after harvest, and the handling, shipping, and processing of the fruit. The treatment of the orchard management aspects of cherry production is purposely brief because the fundamentals underlying production practices for deciduous tree fruits are similar and are discussed adequately in a number of books.

Free use has been made of published results of research, and an effort has been made to establish authority for the material presented. A complete list of citations is supplied for each of the areas covered in order to assist the reader who may wish to read further on any particular topic.

I am deeply grateful to those who reviewed portions of the original manuscript. Those deserving special mention are: Professors H. B. Tukey, W. F. Robertson, C. E. Russell, A. L. Kenworthy, A. E. Mitchell, Ray Hutson, and Donald Cation of Michigan State College; Mr. A. J. Rogers of Traverse City, Michigan; Professors E. M. Mrak, F. W. Allen, and L. L. Claypool of the University of California; Professors E. H. Wiegand and Henry Hartman of Oregon State College; Dr. Fiske Gerhardt of the United States Department of Agriculture; and Dr. C. S. Pederson of Cornell University. Most of the original drawings were made by Mr. K. T. Marshall. The sources of photographs are acknowledged in the accompanying legends. Finally, I am especially thankful to Dr. Z. I. Kertesz for guidance in outlining the text to integrate it with others of the series on "Economic Crops," and for very helpful suggestions for a substantial condensation of the original manuscript.

ROY E. MARSHALL

East Lansing, Michigan
February, 1954

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THE HISTORY OF THE CHERRY

1. History of Cultivated Cherries

Original Habitats. The sweet cherry, *Prunus avium*, probably came from the region between the Caspian and Black Seas. This is the region of greatest communal intensity though it grows in a typically wild state in Transcaucasia, the adjacent regions of Asia Minor, and as far east as northern India. Wild trees inhabit all of Continental Europe in which cultivated varieties of the species can be grown but it is likely that birds and animals were instrumental in disseminating the seeds from the Caspian-Black Sea region. The sweet cherry has long grown spontaneously over a widely extended territory and may have been domesticated in widely separated regions.¹

DeCandolle² limits the original habitat of the red or sour cherry, *Prunus cerasus*, "from the Caspian Sea to the environments of Constantinople" but Hedrick¹ thinks he may have been over cautious. The latter suggests that the source was the much more extended territory lying between Switzerland and the Adriatic Sea on the west and the Caspian Sea and somewhat northward on the east. However, he admits that it is possible that agencies other than man may have extended the area in remote times from DeCandolle's smaller area of origin. In general, pomologists are inclined to assume that both the sweet and the red cherries originated in the same region and that the latter may have been derived from the former.³⁻⁵ The red cherry is a favorite food of many birds that have scattered the seed over many parts of the continents of the eastern hemisphere, possibly before the

The cultivated species of *Prunus cerasus* generally have been designated as *sour cherries* in pomological literature. They also have been called *pie cherries*, *red sour cherries*, *red tart cherries*, in recent years. The last three names are given preference in commerce. They are designated as *red cherries* in this book because this terminology is used by such trade organizations as the National Cannery Association and the National Red Cherry Institute.

arrival of man. It also grows wild in some regions as an escape from cultivation.

The fruits of other species of cherries do not enter into interstate commerce. Hence, their original habitats will be discussed very briefly in a subsequent chapter.

Early Culture in Europe. The earliest records of the cultivation of the cherry indicate that it was first domesticated in Greece. Theophrastus described the cherry 300 B.C., but it probably was cultivated several centuries earlier, possibly more for the wood than for the fruit.¹ Pliny names and describes 10 varieties grown in Italy, but Hedrick suggests that it is hardly probable that Pliny knew and described all of the cherries grown in his country. As further proof that the Romans cultivated the cherry long before Pliny's time, Hedrick calls attention to a discussion of the apparently well-known process of grafting cherries in a book written by Marcus Terentius Varro in 37 B.C.

Pliny mentions England, Germany, Belgium and Portugal in connection with the cherry and Hedrick¹ assumes that by Christ's time or shortly thereafter it must have been grown in other countries that border or that lie between those mentioned.

Little is known about the development of the cherry between ancient and modern times. Less than a score of new varieties were brought into cultivation between Pliny's time and the sixteenth century. The cherry seems to have been cultivated to a greater extent in Germany than in other European countries two to three centuries ago, but the Germans did not give names to more than a few of the most distinct varieties until well into the eighteenth century.¹

According to Pliny, the Romans, before the middle of the first century, brought cherries to England where they became firmly established in Kent. With the expulsion of the Romans, fruit growing, along with agriculture, became almost a lost art and it is probable that the cherry was lost to cultivation during the Teutonic invasions. A revival of cherry culture in England did not take place until the monks established monasteries upon the reintroduction of Christianity.¹

The English herbalists of the sixteenth and seventeenth centuries describe a number of varieties of both *Prunus avium* and *Prunus cerasus* as well as sorts apparently belonging to the other species. Hedrick¹ stated that the well-known Yellow Spanish variety of today is the Spanish Cherry described by one of the herbalists 350 years ago,

and that some other varieties still available were known to these Elizabethan herbalists.

It is thus apparent that the cherry has been in existence as a cultivated fruit since the dawn of civilization but that little was accomplished in improving it until the sixteenth and seventeenth centuries. This may have been due to the fact that the cherry is more fixed in characteristics than other stone fruits; it reproduces truer to type than other fruits when seed propagated.

During the past 250 to 300 years progress in cherry culture has been very rapid. Many new varieties were originated in England and other European countries.

2. The Cherry in America

Colonial Plantings. The cherry was one of the fruits brought to America by the early colonists. The early French settlers brought seeds from Normandy that were planted in Nova Scotia, Cape Breton, Prince Edward Island and the settlements along the St. Lawrence River. The early New England colonists must have planted both sweet and red cherries as well as other fruits. The records of early New England mention enormous cherry trees in fields, woods, and fence rows, indicating that these trees were escapes from very early cultivation. These early plantations apparently were grown from seed.¹

The nursery established by Robert Prince at Flushing, Long Island, in 1730 advertised budded or grafted cherry trees for sale in 1767, indicating that trees offered for sale prior to this time may have propagated from seeds. The third proprietor of this nursery, however, listed more than 20 named varieties which were under cultivation in this country in 1804.¹ Thus, it is probable that cherries grown by the Dutch from New Amsterdam northward along the Hudson River and its tributaries during the latter part of the seventeenth and in the eighteenth centuries were propagated from seed.

Cherries were also planted by the early colonists in Pennsylvania, New Jersey, Delaware, Virginia, and North Carolina, where it is reported that the cherry was one of the easiest fruits to propagate and cultivate. Even as early as 1676 cherries were reported to have grown in "notable abundance" in Virginia.¹

Introduction to Western States. The early French settlers evidently planted cherries, as well as other fruits, in gardens in and about

the ports established at such places as Detroit, Michigan; Vincennes, Indiana; St. Louis, Missouri; and settlements in Illinois. The cherry was probably introduced into California by the Franciscan monks during the latter part of the eighteenth century. It continued to be cultivated, more or less sparsely, until the influx of the gold seekers in 1849, some of whom noted the opportunity for growing fruit and began the importation of seeds and plants.¹

Some fruits had been grown in Oregon by employees of the Hudson Bay Company prior to 1847, but they were seedlings rather than bud-propagated trees. In that year, however, fruit growing had its real inception in Oregon for Henderson Lewelling crossed the plains from Henry County, Iowa, with a choice collection of grafted trees in boxes of soil in a wagon drawn by oxen. When he arrived at what is now Milwaukie, Oregon, in the late fall of 1847, 300 of the trees were alive and these were planted. Among the varieties of cherries were the Biggarreau, The English Morello and other types. The label of one of the cherry trees was lost and he renamed it Royal Ann. Though the variety had been cultivated for three centuries and had been known as Napoleon since 1820, the name Royal Ann has persisted on the Pacific Coast.¹

Seth Lewelling, a brother and successor of Henderson, grew many cherries from seeds from which have come a number of varieties that have made Oregon famous. Among the varieties originated at the Lewelling nursery, Republican, Lincoln, Willamette and Bing proved to be the most desirable. Others were encouraged by this success to breed cherries in the Northwest resulting in the development of the well-known Lambert and Oregon varieties.¹

The Cherry in the Nineteenth Century. Despite the facts that the early colonists cultivated the cherry and that it moved westward in America with the early pioneers, it was grown almost entirely in the farm orchard or in the backyard garden for home use and had very limited local sales until the beginning of the present century. It was one of the favored fruits for such purposes because the trees required very little attention and the fruits provided a distinctive flavor and quality for both fresh consumption and preservation. Furthermore, the tree provided an aesthetic appeal that made it a favorite in the gardens.

Cherry variety lists have undergone less change during the past century than have the lists for most other fruits. Thus, a greater degree of varietal standardization has been developed than exists with other

fruits. While the variety list is not an extensive one compared to that of some other fruits, it is nevertheless a rather formidable one. Hedrick¹ described 1145 varieties in 1914 and a few have been added to the American list during the past one-third of a century.

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THE CHERRY INDUSTRY

The United States census reports did not segregate sweet and red cherries until recently. Hence, any long range study of the development of the industry must be limited to trends in combined sweet and red cherry plantings.

Statistics for most fruits may be divided into two categories: total crop production and commercial production. Total crop production includes fruits grown in the family gardens or small farm orchards as well as those grown for sale, while commercial production is that portion entering into commerce. Fruit growers, obviously, are interested in commercial production rather than in total crop production. Prior to the development of any fruit industry, however, there is usually a period of varying length during which the production is practically all from general farm orchards and garden plantings. The cherry has not been an exception to this general trend of development. It, therefore, seems desirable to give some consideration to the trends preceding and during the establishment of an extensive commercial industry.

1. Total Bearing Trees

The cherry seems to have been principally a farm orchard and family garden fruit in most portions of the United States until the end of the last century. Kansas, a state that we now know has only a very limited area suitable for growing tree fruits on a commercial scale, led all the states in numbers of bearing cherry trees in the last decade of the past century. It had more than one million bearing trees in 1889 and again in 1899. Indiana ranked second in 1889 and other leading states in the last decade of the last century were: Pennsylvania, Michigan, New York, Missouri, Ohio, Illinois, California and Iowa. Most of the better general farms at that time had at least a few cherry trees to supply the family needs for fresh fruit in early summer and for home-canned cherries.

Bearing tree populations evidently reached their maxima in several of the states about the turn of the century, but at least 13 states continued to show increases in numbers of bearing trees for another decade. If data were available, it is possible they would show that the maximum number of bearing cherry trees in the United States was reached sometime during the first decade of the current century. In other words, there were probably more farms having cherry trees at

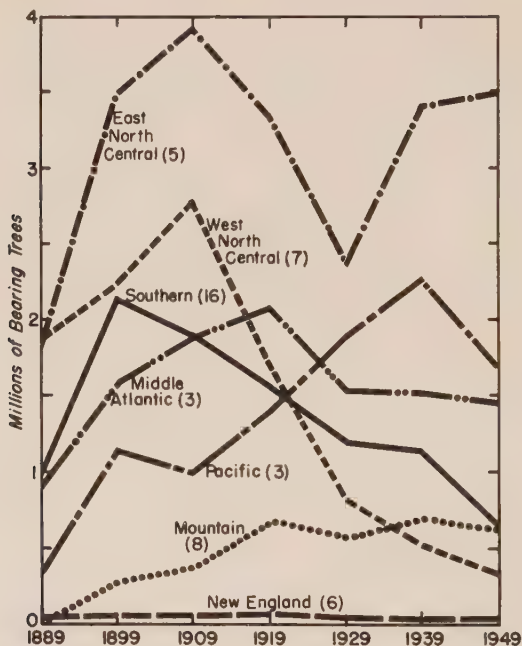


Figure 1. Trends in number of bearing cherry trees by geographic divisions, 1899–1949. The numbers in parentheses indicate the numbers of states in each geographic division. Data for 1949 are preliminary.¹

that time than at any other time in the history of the country. This is apparent in both Figures 1 and 2.

In general, the states that were to become important commercially, maintained or continued to increase bearing cherry tree populations after 1909, while those that were destined to become relatively unimportant in commercial production declined in tree numbers. The most substantial downward trends occurred in the southern tier of the east

north central, in all of the west north central, and in the southern states (Figure 1). Only 12 states had more than 100,000 bearing cherry trees at the time the 1950 census was taken. The 16 southern states, as a group, have never exceeded 18% of the reported total bearing tree population of the United States. New England has never been important in cherry production.

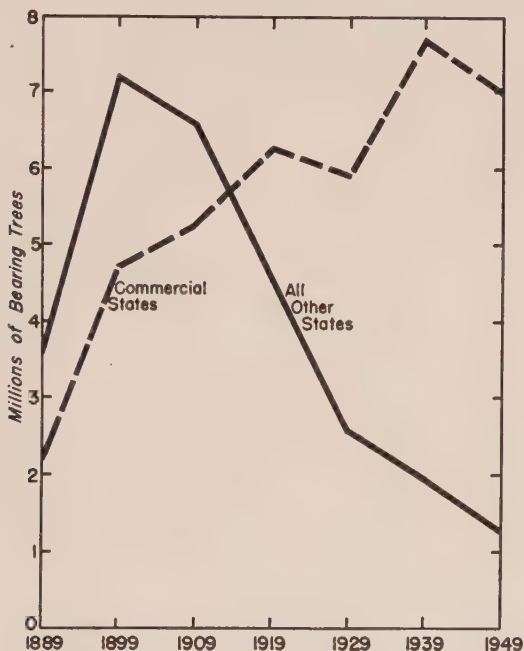


Figure 2. Trends in bearing cherry tree populations for 12 states recognized as "commercial" (New York, Pennsylvania, Ohio, Michigan, Wisconsin, Colorado, Utah, Montana, Idaho, Washington, Oregon, and California) and other non-commercial states.¹

2. Commercial Production

A. BEARING TREES

The trend lines in Figure 1 indicate that the states that have maintained importance in cherry production are in the Middle Atlantic, east north central, mountain and Pacific geographic divisions of the United States. States having more than 200,000 bearing trees in pre-

liminary tabulations for the 1950 census were: Michigan with 2,421,000, New York with 1,007,000, Wisconsin with 768,000, Oregon with 749,000, California with 702,000, Pennsylvania with 420,000, Colorado with 249,000 and Washington with 223,000.

During the past half-century, the bearing tree populations in the 12 commercial states increased at an approximate average rate of 47,000 per year (Figure 2). The slight decline in numbers of bearing trees between 1919 and 1929 is largely due to the rather substantial decreases in Pennsylvania and Ohio, two states that had, and still have,



Figure 3. Approximate distribution of cherry trees in the United States.¹ Each dot represents 50,000 bearing sweet cherry trees and each circle represents 100,000 red cherry trees.

many small family plantings. Substantial declines in numbers of bearing trees occurred in Pennsylvania, Ohio, Colorado, Washington and California between 1939 and 1949.

Approximate distributions of sweet and red cherry tree populations are shown in Figure 3. It is not possible to locate enough dots in areas of intensified plantings to show the exact location of the plantings, nor is it possible to show precisely where the trees are in areas of space plantings. Consequently, the dots for intensified areas, such as Grand Traverse and Leelanau counties in Michigan, Dorr County in Wis-

consin and San Joaquin County in California, overflow into adjoining counties that may be relatively unimportant for cherry production and, on the other hand, one dot or circle may have to serve for more than one state.

Plantings of sweet cherries are concentrated mostly in the general Bay Area of California, western Oregon, and central Washington. The mountain states and those bordering on the Great Lakes have much more scattered plantings.

The densest plantings of red cherries occur in the eastern shore region of Lake Michigan, more particularly in the Grand Traverse Region of Michigan, on the Dorr County Peninsula of Wisconsin, and in western New York. Plantings in Pennsylvania, northern Ohio, Colorado and the western portions of Washington and Oregon are much less extensive and more scattered.

B. COMMERCIAL TONNAGE

California was the leading state in average annual cherry production in the United States through 1927, when Michigan assumed the lead to maintain it rather consistently, producing approximately 35% of the total for the 12 commercial states during the five-year period ending with 1952 (Table 1). Since California relinquished its lead in total production of all cherries in 1928, it ranked second among the states for a few years, then relinquished second place to Washington and finally regained second ranking. The apparent ranking of the states in commercial production of all cherries for the five-year period ending in 1952 was: Michigan, California, New York, Oregon, Washington, Wisconsin, Pennsylvania, Utah, Colorado, Idaho, Ohio and Montana.

The general trend in production of cherries in commercial states is shown in Figure 4. The distribution of the dots shows that production has varied considerably at times although there is no evidence of a tendency toward biennial production. The very low production in 1943 and the lows for 1921, 1927, and 1945 may be attributed largely to damage caused by spring frosts in certain areas, more particularly in the eastern states.

The trend line in Figure 4 shows an average annual production gain of nearly 5,500 tons from 1919 to 1942, and could have been shown as a straight line trend for this period. From 1943 through 1952, production has been variable, partly because spring frost damage lowered production very substantially in the eastern states in some years. The

CHERRIES AND CHERRY PRODUCTS

TABLE 1. AVERAGE ANNUAL PRODUCTION OF CHERRIES, 1919-1937, AND PRODUCTION OF SWEET AND RED CHERRIES, 1938-1952,² IN TONS^a

Years	New York		Pennsylvania		Ohio		Michigan	
	Sweet	Red	Sweet	Red	Sweet	Red	Sweet	Red
1919-1922								
			b		b			11,960
1923-1927		9,540						14,050
		14,750	b		b			26,890
1928-1932		16,890	7,690 ^c		4,190 ^c			37,380
1933-1937		17,960	7,040		4,860			
1938	1,600	15,500	1,300	4,000	100	1,880	2,800	19,000
1939	2,200	26,000	2,000	7,200	890	3,780	2,600	38,400
1940	2,000	20,000	2,100	6,300	660	3,160	3,500	45,600
1941	2,800	14,500	2,100	7,300	840	4,340	3,800	27,700
1942	3,000	27,000	1,900	7,100	780	4,050	3,900	46,500
1943	1,000	10,100	700	2,900	120	650	1,600	10,800
1944	2,500	19,400	1,900	7,900	760	2,770	4,600	50,000
1945	2,200	7,300	700	3,600	250	2,200	500	14,000
1946	1,400	15,500	700	4,600	200	2,100	4,500	60,500
1947	2,200	14,800	900	4,600	280	2,120	4,000	49,500
1948	3,000	20,500	900	6,500	260	1,760	3,800	69,000
1949	2,900	17,500	1,700	9,000	370	1,910	6,400	60,500
1950	4,600	26,100	1,500	8,400	510	2,860	8,300	98,000
1951 ^d	6,000	30,200	1,600	12,000	520	2,600	6,800	76,000
1952 ^d	4,000	20,100	1,600	8,900	510	2,280	8,300	62,500

II. THE CHERRY INDUSTRY

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Years	Wisconsin		Montana		Idaho		Colorado		Utah	
	Sweet	Red	Sweet	Red	Sweet	Red	Sweet	Red	Sweet	Red
1919-1922		5,000		b		2,570		3,810		b
1923-1927		5,890		325 ^c		2,510		4,550		4,600 ^e
1928-1932		8,220		530		3,170		3,330		3,400
1933-1937		8,530		400		2,160		3,070		2,560
1938	—	7,700	b	290	1,650	440	560	4,240	2,800	2,400
1939	—	7,800	b	220	1,430	410	300	3,000	1,800	1,100
1940	—	13,900	b	260	1,550	530	460	3,080	3,100	2,300
1941	—	15,600	60	300	1,500	550	490	2,810	3,900	1,900
1942	—	8,400	110	150	1,500	460	220	2,830	2,200	1,100
1943	—	2,600	40	430	1,960	660	400	3,900	4,000	2,800
1944	—	15,000	610	470	2,640	660	500	5,400	3,300	3,400
1945	—	7,300	480	370	2,460	700	360	2,200	4,300	2,600
1946	—	20,000	700	60	3,520	440	250	3,200	3,900	3,600
1947	—	9,000	1,120	410	2,380	680	490	3,960	3,500	3,200
1948	—	25,000	500	350	3,260	650	530	5,000	3,900	2,500
1949	—	11,600	1,760	310	3,500	630	370	3,380	2,900	1,900
1950	—	13,000	320	230	1,250	350	230	1,600	440	800
1951 ^d	—	14,500	40	30	3,250	610	380	3,000	4,000	3,200
1952 ^d	—	10,900	1,980	330	3,920	790	1,020	1,050	4,500	2,700

table continued

CHERRIES AND CHERRY PRODUCTS

TABLE 1 (continued)

Years	Washington		Oregon		California		Total
	Sweet	Red	Sweet	Red	Sweet	Red	
1919-1922	^b		^b				
1923-1927	6,960 ^c		11,000 ^c		14,980		47,840
1928-1932	11,540		10,340		15,100		76,750
1933-1937	16,100		14,250		17,880		111,390
					20,300		134,680
1938	15,700	6,200	16,200	2,550	25,200	67,910	63,900
1939	19,300	6,000	18,100	2,450	33,000	81,620	96,360
1940	21,300	6,200	20,300	2,150	11,000	65,970	103,480
1941	24,700	3,500	18,100	1,200	21,000	79,380	79,700
1942	22,800	4,100	16,100	2,350	28,000	80,510	104,040
1943	25,700	3,240	20,100	2,200	16,000	71,620	40,280
1944	21,200	5,600	17,800	2,600	27,000	82,810	113,200
1945	32,400	4,090	19,700	2,100	38,000	101,350	46,460
1946	32,200	4,300	30,000	2,900	34,000	111,370	117,200
1947	25,600	4,200	10,800	1,400	28,000	79,270	93,870
1948	21,300	1,800	18,500	1,700	23,500	79,450	134,760
1949	33,200	3,000	31,200	2,800	44,000	128,300	112,530
1950	16,500	2,900	17,400	2,400	31,000	82,050	156,640
1951 ^d	11,480	3,500	16,700	3,700	19,800	70,570	149,340
1952 ^d	14,900	1,200	18,000	2,600	39,500	98,230	113,350

^a Cherries not harvested and those harvested but not utilized are not included in this table.^b Estimates not obtained for these years.^c Averages are for last four of the five years.^d Preliminary estimates.

average production for sweet and red cherries from 1938 through 1952 is similar, though the proportions of each have varied substantially in some years (Table 1).

From the statistics on processed red cherries made available by Nelson and Sulerud³ prior to 1932, that published by Marshall⁴ for the years 1926 to 1934, inclusive, the latter's unpublished data for 1935 to 1937, inclusive, and by making allowances for non-processed cherries it is possible to estimate the production of red cherries for each of 18 years prior to the segregation of sweet and red cherry production by

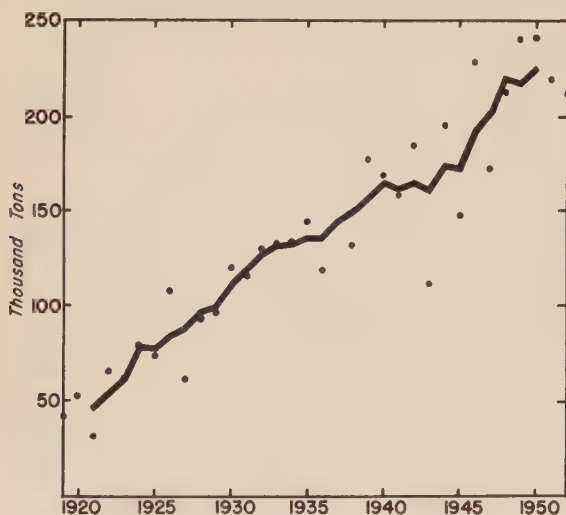


Figure 4. Trends in the production of cherries in 12 commercial states, 1919-1952. The dots show production of all cherries for individual years. The trend line for production of all cherries is based on five-year moving averages.

the United States Department of Agriculture. While the accuracy of such a procedure may be questioned, it is believed the data are sufficiently usable to justify the calculation of a straight line trend for the 31-year period ending in 1952. By deducting the calculated production of red cherries for each year prior to 1938 from the total production of cherries shown in Table 1, it is possible to arrive at estimates for sweet cherry production. The trend lines in Figure 5 are based on such estimates.

Although production of both sweet and red cherries has increased rapidly throughout the 31-year period included in the graph, production of red cherries has increased approximately 1,400 tons per year more than the average gain for sweet cherries. However, during the latter half of the years included in Figure 5, red cherry production increased at the rate of 4,500 tons annually while sweet cherry production increased at an average rate of 2,100 tons. Approximately 60% of the cherries produced in commercial states during the five-year period ending in 1952 were red varieties.

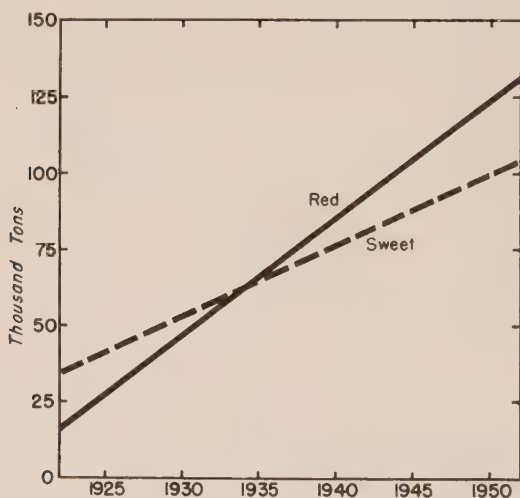


Figure 5. General trends in production of sweet and red cherries for 12 commercial states, 1922–1952.²⁻⁴

Regional Production of Cherries. In a rather general way, industry refers to “eastern” and “western” cherry production. The eastern region comprises the states of New York, Pennsylvania, Ohio, Michigan, and Wisconsin, while the states of Colorado, Utah, Montana, Idaho, Washington, Oregon, and California make up the western region.

The average annual production for the five eastern states was approximately 135,000 tons of cherries having value in 1949–1952, while that for the seven western states was 90,000 tons (Table 1).

Thus, the eastern states produced 60% of all cherries during the 5-year period.

Sweet cherry production is concentrated in the Pacific Coast states. These states, along with the others comprising the western region, produced approximately 86% of the sweet cherries grown in the 12 commercial states during the five-year period ending with 1952. California produced nearly 40% of the sweet cherries grown in the western states and 34% of those produced in all commercial states during the five-year period. Approximately 45% of the sweet cherries produced during this period were grown in Washington and Oregon.

Commercial red cherry production occurs in all of the 12 states except California. The five eastern states, however, grew 92% of the red cherries produced in commercial states during the years from 1949 to 1952, inclusive. Michigan produced 60% of the red cherries grown in the eastern states and 55% of all commercially grown red cherries having value for these years.

Production of Cherries Not Utilized. Preceding pages have dealt with the production of cherries having value. These cherries presumably were consumed in one way or another. Several thousand tons of cherries have been produced in the commercial states that were not harvested mainly because of unfavorable market conditions or because of the lack of labor. In addition, several hundreds of tons of cherries were harvested but were not utilized due to excessive cullage resulting from rain or other causes. Since such tonnages in some years were substantial, these cherries deserve some consideration in a study of production trends.

The quantities of cherries not harvested because of economic conditions varied during the years for which records are available from zero in 1944 to 14,210 tons in 1932, the latter year being in the midst of an economic depression period. Other years in which there were substantial quantities of non-harvested cherries were 1931 with 10,150 tons, 1938 with 10,500 tons, 1939 with 6,510 tons, 1942 with 10,960 tons, 1949 with 6,600 tons and 1952 with 6,000 tons. Economic conditions account for all of the above except for 1949, when excessive cracking of sweet cherries occurred in the Northwestern states, and 1952 when wind caused excessive bruising of red cherries in Michigan. The quantities not harvested for the years 1938 to 1952, inclusive, averaged 2,700 tons of sweet cherries and 650 tons of red cherries per year.²

Estimates of cherries harvested but not utilized due to excessive cullage resulting from rain and other causes for the years 1938 to 1952, inclusive, ranged from none for both sweets and reds in 1948 to 2,800 tons of sweet cherries in 1949 and 8,700 tons of red cherries in 1951. The average annual cullage reported for the 15 years were 800 tons each for sweet and for red cherries. Estimates made for recent years indicate that such losses have been greater with sweet varieties than with red cherries. The fact that rain is specifically mentioned as a cause of these losses indicates that cracking and the brown rot fungus were the principal factors involved in the losses for sweet cherries. The heavy cullage of red cherries in 1951, as well as the large tonnage not harvested in 1952, were due to the initiation of rigid grading practices at processing plants in Michigan.

C. FARM VALUE OF CHERRIES

Sweet cherries produced in 11 states from 1938 to 1952, inclusive, ranged in average farm price from \$75.70 per ton in 1938 to \$297 per ton in 1951. The total value of production for the commercial states ranged from \$5,139,000 in 1938 to \$31,160,000 in 1946. The average annual farm value for sweet cherries for the 15 years was \$17,280,000 and for the 1948-1952 period it was \$20,460,000.²

Red cherries produced in 11 states from 1938 to 1952, inclusive, ranged in farm price from \$43.20 per ton in 1939 to \$301 in 1946. The farm values of the crops ranged from \$3,586,000 in 1938 to \$34,942,000 in 1946. The average yearly value of the commercial red cherry crops was \$14,909,000 during the 15-year period and for 1948-1952 period it was \$19,909,000.²

3. Utilization of Cherries

Approximately 4,800 tons of sweet and 2,200 tons of red cherries were canned in 1909 and 4,300 tons of sweet and 4,700 tons of red cherries in 1914. The former year was probably a very early one in the commercial canning of substantial portions of both sweet and red cherries.³

The major portion of Table 2 has been compiled from calculated conversions of data assembled on canned and frozen packs, brined fruit, and carlot shipments of fresh cherries for a number of years prior to 1932³ and estimates of the quantities of red cherries converted to

canned and frozen packs for the years 1926 to 1934, inclusive.⁴ These data must therefore be regarded as approximations.

The estimated sales of fresh sweet cherries ranged from approximately 8,000 tons in 1921 to 18,000 tons in 1926 for the 12 years for which data are available. There appears to have been no definite trend nor a correlation between production of all cherries for commercial purposes and carlot shipments of this fruit.

TABLE 2. ESTIMATED UTILIZATION OF CHERRIES PRODUCED IN COMMERCIAL STATES, 1919-1937, IN THOUSANDS OF TONS

Year	Production of all varieties having value ^a	Sweet cherries			Red cherries	
		Fresh sales ^b	Canned	Brined	Canned	Frozen
1919	40	<i>g</i>	15 ^b	<i>g</i>	7 ^b	<i>g</i>
1920	53	10	16 ^b	<i>g</i>	11 ^b	<i>g</i>
1921	32	8	7 ^b	<i>g</i>	6 ^b	<i>g</i>
1922	66	13	16 ^b	<i>g</i>	10 ^b	<i>g</i>
1923	62	14	17 ^b	<i>g</i>	16 ^b	<i>g</i>
1924	79	12	11 ^b	<i>g</i>	25 ^b	<i>g</i>
1925	74	13	10 ^b	<i>g</i>	18 ^b	<i>g</i>
1926	108	18	22 ^b	1 ^b	25 ^c	8 ^c
1927	61	8	9 ^b	1 ^b	14 ^c	1 ^c
1928	94	15	15 ^b	1 ^b	28 ^c	7 ^c
1929	96	13	16 ^c	2 ^{c,d}	24 ^c	6 ^{c,f}
1930	120	14	19 ^c	4 ^{c,d}	30 ^c	21 ^{c,f}
1931	116	11	6 ^c	7 ^{c,d}	35 ^c	7 ^{c,f}
1932	130	<i>g</i>	8 ^c	8 ^{c,d}	32 ^c	4 ^{c,f}
1933	132	<i>g</i>	14 ^c	13 ^{c,g}	40 ^c	3 ^{c,f}
1934	133	<i>g</i>	8 ^c	9 ^{c,d}	43 ^c	9 ^{c,f}
1935	144	<i>g</i>	8 ^c	13 ^{c,d}	60 ^c	10 ^{c,f}
1936	120	<i>g</i>	9 ^c	22 ^{c,d}	34 ^c	6 ^{c,f}
1937	144	<i>g</i>	8 ^c	23 ^{c,d}	57 ^c	17 ^{c,f}

^a *Agricultural Statistics*, U.S.D.A., 1946.

^b Calculated from data by M. N. Nelson and G. L. Sulerud, *Oregon Agr. Exp. Sta. Bull.* 310 (1935).

^c *Agricultural Statistics*, U. S. Dept. Agr. 1943.

^d Includes small quantities of red cherries.

^e R. E. Marshall, *Michigan Agr. Exp. Sta. Spec. Bull.* 258, 1935.

^f Includes small quantities of sweet cherries.

^g Information not available.

The quantities of sweet cherries canned during the 19-year period covered by Table 2 varied rather substantially. The heaviest pack for the period under consideration occurred in 1926 when production was relatively high. The light packs for the last seven of the 19 years may

CHERRIES AND CHERRY PRODUCTS

TABLE 3. UTILIZATION OF CHERRIES PRODUCED IN 12 COMMERCIAL STATES, 1938-1951,^a IN THOUSANDS OF TONS

Year	Sweet cherries						Red cherries			
	Farm household use	Fresh sales	Processed			Farm household use	Fresh sales	Processed		
			Canned	Brined	Other ^b			Canned	Frozen	Other ^a
1938	6	33	12	16	^b	6	13	34	9	2
1939	7	35	20	19	^b	7	14	55	17	3
1940	7	31	12	16	^b	7	13	59	20	4
1941	7	37	17	19	^b	7	10	38	22	3
1942	7	36	19	17	1	7	13	60	22	2
1943	5	35	15	14	2	5	10	13	13	^b
1944	7	40	14	20	3	7	13	55	35	2
1945	6	43	22	24	8	4	7	25	9	1
1946	6	37	30	31	7	6	10	56	44	1
1947	6	36	10	25	1	6	9	41	35	1
1948	6	27	16	30	1	6	11	67	46	5
1949	5	53	27	41	1	6	11	58	35	1
1950	5	35	12	30	^b	5	9	88	53	1
1951	5	27	14	25	1	5	9	83	50	2
Av. %	7	43	20	28	2	6	11	52	29	2

^a Includes fruit used for juice, wine, preserves, candied cherries and sweet cherries, frozen and red cherries brined.

^b Less than 500 tons.

have been due to general economic conditions and the accompanying low prices for cherries.

An era of acceleration in the quantities of sweet cherries processed by brining seems to have started about 1930. This was about the time that imports from European countries declined very substantially because of the establishment of a tariff of $9\frac{1}{2}$ cents per pound. Imports of this product declined from 22,362,000 pounds in 1929-1930 to 1,702,000 pounds in 1932-1933.⁵

A substantial upward trend in quantities of red cherries canned occurred during the 19-year period covered by Table 2. Estimates of the average amounts canned per year for the first five-year period were 12,500 tons compared with an average of 46,800 tons annually for the last five years shown in the table.

Some red cherries were frozen in the early nineteen-twenties but records indicating the extent of the early frozen packs are not available. The data presented for this item in Table 2 show a fluctuating pack. The very heavy pack of 1930 apparently was much greater than the consuming public was ready to absorb. Much of the frozen pack for that year was put up in New York, where facilities were inadequate to can the exceptionally heavy factory receipts, and the last of it did not move out of the warehouses until the summer of 1932.⁴ The smaller packs for the next several years were, in part, compensating for the over-optimistic pack of 1930, and, in part, due to economic conditions.

Table 3 shows that both the quantities and proportions of the crops of both sweet and red cherries have fluctuated considerably in the ways in which the cherries have been utilized since 1938, the first year for which complete segregated information was made available.

The utilization of both sweet and red cherries for farm household use has been rather uniform from year to year but accounts for only five to nine percent of the production of either type of fruit.

Fresh fruit sales of sweet cherries have ranged from approximately 27,000 tons in 1948 and 1951 to 53,000 tons in 1949 and have accounted for about 43% of the average production for the 14-year period. Red cherries are in much less demand on fresh fruit markets than the sweet ones. Fresh fruit sales for the former have ranged from approximately 7,000 to 14,000 tons, and account for an average of about 11% of production in commercial states.

One-half of the sweet cherries have been processed during the 14-year period under consideration and approximately 40% of these

have been processed by canning. The percentage of sweet cherries that were canned during the last five years was slightly less than that utilized in this way during the first five of the 14 years.

While there has been a substantial increase in the quantities of red cherries canned during the years covered by Table 3, there has been a slight decrease in the proportions of the total commercial crops that were utilized by canning. However, commercial canning still utilized more than one-half of the total commercial production during the 1947-1951 period.

The quantities of sweet cherries frozen in 1945 and 1946 amounted to approximately seven and five percent, respectively, of the total commercial productions, but the quantities frozen in other years were negligible. These amounts are included in the "other" column of Table 3. It is not anticipated that freezing will become a major outlet for sweet cherries.

Frozen red cherries have continued to gain in popularity. The average annual proportion of red cherries frozen during the 14 years was approximately 29% but the percentage of the crop frozen during the last five of the 14 years was 34.

The demand for domestic brined cherries increased through the period of years covered by Table 3; in fact, there is some indication that domestic brining has taken an upward trend in very recent years. All but negligible amounts of these brined cherries are processed from sweet varieties.

Cherries are also utilized for such other processing as the making of wine, juice, preserves and candied cherries. The quantities of both types of cherries used for such purposes seldom exceeded 3,000 tons, and the greater portion of these have been red cherries.

Further studies on production trends for red cherries and per capita consumption of all cherries have been reported by Marshall⁷ and Johnson,⁸ respectively.

4. United States Foreign Trade

The combined exports of cherries in processed or fresh forms have not exceeded 4,000 tons for any years for which adequate records are available (Table 4), and for most of the years from 1929 to 1949, inclusive, exports have ranged from slightly over 100 to less than 1,000 tons for canned cherries and between 300 and 600 tons for fresh

TABLE 4. UNITED STATES FOREIGN TRADE, 1929-1946⁶

Year, beginning in July	Exports, tons		Imports, tons	
	Canned	Fresh	Natural, sulfured, or in brine	Dried or preserved
1929	949		11,181	433
1930	616		3,963	640
1931	322		2,972	74
1932	291		851	50
1933	520		842	34
1934	702		746	13
1935	823	399 ^a	772	13
1936	935	322	451	14
1937	1,328	735	916	29
1938	2,956	1,030	554	14
1939	1,307	378	1,084	15
1940	411	522	22	^b
1941	503	501	10	^b
1942	394	443	4	^b
1943	129	403	10	31
1944	127	561	2	7
1945	588	388	67	^b
1946	1,363	1,019	2,296	2
1947	568	806	5,250	1
1948	475	25	2,047	5
1949	266	625	2,348	29
1950	303	623	3,556	252

^a Not segregated prior to 1935.^b Less than 0.25 ton.

cherries. These are of little concern in the commercial production of cherries.

Imports of natural, sulfured, or brined cherries are reported at 11,181 tons for the year beginning with July 1, 1929 (Table 4), after which they declined sharply to approximately 850 tons in 1932 because of import tariffs. Imports stabilized at approximately this level of tonnage until World War II when they practically ceased. When tariff restrictions were eased in 1946, imports increased substantially.

5. Production and Utilization in Canada

Commercial production of all varieties of cherries for the important producing provinces in Canada are presented in Table 5. It

may be assumed that the major proportion of the cherries produced in Ontario were red varieties while most of those grown in British Columbia were sweet cherries.

The average annual production for the years 1942 to 1952, inclusive, was in excess of 8,500 tons. More than 60% of this average production was in Ontario. Average annual production increased substantially in Ontario during the 11-year period while that for British Columbia decreased slightly.

Nearly 55% of the commercial crops produced in the two Canadian provinces during the 11-year period was processed. The

TABLE 5. COMMERCIAL PRODUCTION AND UTILIZATION OF CHERRIES IN CANADA 1942-1952, IN TONS^a

Year	Ontario		British Columbia		Total	
	Production	Processed	Production	Processed	Production	Processed
1942	6,800	4,800	2,300	1,100	9,100	5,900
1943	2,800	1,500	2,600	800	5,400	2,300
1944	3,500	2,200	3,600	1,300	7,100	3,500
1945	1,000	500	4,900	1,500	5,900	2,000
1946	4,600	3,800	3,800	1,600	8,400	5,400
1947	3,200	2,216	4,275	1,799	7,475	4,015
1948	6,525	4,794	3,275	1,405	9,800	6,199
1949	6,750	4,642	5,204	1,050	11,954	5,692
1950	6,875	4,761	1,645	378	8,520	5,139
1951	8,700	6,143	1,300	270	10,000	6,413
1952	7,250	4,084	2,904	632	10,154	4,716

^a Data for 1942 to 1946 from *Market Service*, Dom. Dept. Agr., 18 (52), 1947; 1947 and 1948 from F. J. Perry, Fruit & Veg. Div., Canadian Dept. of Agr., 1949 to 1952 from N. F. Sherman, Dom. Bur. of Statistics and A. C. Lander, Tree Fruits Ltd., Kelowa, B.C.

average percentage processed in Ontario was 68% while that for British Columbia was 33%. This difference in proportions of the crops processed in the two provinces is due to the fact that most of the red cherries are processed while substantial quantities of sweet cherries are shipped for fresh fruit consumption.

6. World Production of Cherries

The average production of all types of cherries for three five-year periods and one three-year period is presented by continents and countries and for the world in Table 6. The total world production has

TABLE 6. PRODUCTION OF CHERRIES IN SPECIFIED COUNTRIES—AVERAGES IN SHORT TONS FOR 1935-39, 1940-44, 1945-49 AND 1950-52^a

Continent and Country	1935-39	1940-44	1945-49	1950-52 ^a
North America				
Canada	5,250	6,925	8,785	10,706
United States	149,094	168,550	203,078	230,183
<i>Total</i>	154,344	175,475	211,863	240,889
Europe				
Austria	17,624	19,510	22,140	24,000
Belgium-Luxembourg	15,817	12,637	23,319	26,276
Czechoslovakia	57,776	29,677	63,604	^b
Denmark	810	571	808	961
France	55,784	43,960	75,311	81,886
Germany				
Western Zone	95,511	85,074	121,600	182,300
Eastern Zone	65,887	53,938	90,996	^b
Greece	12,125	10,000	8,803	9,266
Hungary	10,000	10,287	14,019	^b
Italy	78,131	80,358	103,530	121,284
Netherlands	5,040	8,070	15,984	24,412
Norway	5,849	4,197	4,228	4,223
Poland	59,440	35,680	55,508	^b
Romania	213,584	101,001	21,267	^b
Spain	32,102	36,688	36,173	35,583
Sweden	10,435	7,320	6,393	8,267
Switzerland	25,243	38,801	47,620	59,799
United Kingdom	12,667	20,317	26,298	20,350
Yugoslavia	41,778	68,052	58,327	51,462
Other Europe	—	—	—	305,254
<i>Total</i>	815,603	666,138	795,928	999,278
Asia				
Lebanon-Syria	146	1,988	2,400	2,252
Turkey	35,925	32,164	38,111	44,276
Japan	5,496	5,456	5,400	3,483
<i>Total</i>	41,567	39,608	45,911	50,011
South America				
Argentina	3,748	4,415	2,436	2,000
Chile	992	450	761	845
<i>Total</i>	4,740	4,865	3,197	2,845
Oceania				
Australia	3,953	4,906	4,808	3,763
New Zealand	279	391	274	373
<i>Total</i>	4,232	5,297	5,082	4,136
<i>World total</i>	1,020,486	891,383	1,061,981	1,253,159

^a 1952 data are preliminary^b Included in "other Europe."

averaged more than one million tons for the years 1935–1952, inclusive. Of this total, approximately 18% have been produced in North America, 77% in Europe, 4% in Asia, and less than 0.5% each in South America and Oceania.

The ten leading countries in the production of cherries during 1935–1952, in descending order, are as follows: Germany (East and West Zones), United States, Italy, Romania, France, Yugoslavia, Czechoslovakia, Poland, Switzerland and Turkey. These ten countries have accounted for approximately 83% of the total world production during the period of years covered in the table. Canada, Netherlands and Switzerland more than doubled production during the years included in Table 6. United States, Belgium and Luxembourg, Germany, Italy, and United Kingdom increased production more than 50% and Austria, France, Hungary and Turkey increased production more than 25%.

The outstanding reduction in tonnage occurred in Romania where the average annual production dropped from approximately 214,000 tons in 1935–1939 to approximately 11,000 tons in 1947–1952. Thus, Romania dropped from the first position in world production (21% of world production in 1935–1939) to one of inconsequence in 1950–1952 (approximately 1% of world production).

Most of the production in Europe and Southwest Asia is sweet cherries. In 1950 and 1951, 89%, 53% and 76% of the cherries produced in Germany, Austria and Turkey, respectively, were sweet varieties.

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9. Foreign Crops and Markets, U.S.D.A. Mimeo. Repts.

SPECIES, GROUPS AND VARIETIES**1. The Genus *Prunus***

The cherry belongs to the genus *Prunus* of the family Rosaceae, or rose family. The genus *Prunus* includes such other well-known stone or drupaceous fruits as the almond, the apricot, the nectarine, the peach, and the plum. Each of these fruits constitutes a distinct group, but the cherry and the plum are so closely related that even botanists have not been able to agree as to whether some border-line species are cherries or plums.

Cherries may be separated from plums by their smaller size and distinctive color of skin, juice and flesh; by texture and distinctive flavor; by growth in corymbose rather than umbelliferous fascicles; by the more globular stone, and by having leaves which are conduplicate, or folded lengthwise along the midrib, while those of the plum are usually convolute, or rolled up, in the bud.¹

Some systematic botanists divide the genus *Prunus* into subgenera, classifying cherries in the sub-genus *Cerasus*. A monographer of *Cerasus* classified 119 species in this sub-genus in 1912, including five from North America, 14 from the western part of the Old World, and more than 100 from the Himalaya Mountains and the region to the east. It is probable that further exploration of west central Asia will add many new species to this sub-group of *Prunus*.¹

Only a few of the recognized species of cherries have been domesticated and still fewer have proved to have value for fruit production or as stocks on which to propagate trees for fruit production. Some of the other species may yield to improvement to furnish either fruit or possibly stocks that are more desirable than those now in general use. Then there is the possibility of utilizing some of these little known species to produce new types through hybridization.

2. The Sweet Cherry

The trees of the sweet cherry, *Prunus avium*, are large, attaining heights of 30 to 40 feet. They range in shape from pyramidal to upright spreading and while they usually develop a central leader, they are open-topped. Branches usually are more or less erect in growth habit. The trees are a little harder than the peach, *Prunus persica*, but not as hardy as the red cherry, *Prunus cerasus*. In favorable environments, the trees may live for a century or more.

The trees have less foliage than trees of the red cherry, but the leaves are larger. The foliage is more or less drooping and is supported by long, stiff petioles.

The fruit of the sweet cherry is large, is cordate in shape, has a deep cavity, and the apex is rounded or pointed. A variety of colors is available from yellow through red to purplish black. The fruit is supported by a stem averaging about 1½ inches in length. The flesh ranges in texture from tender to firm, is sweet, and may be yellow, red or dark purple in color.¹

The wild cherries of this species have been known as Mazzard, bird, wild, crab, and Gean cherries. They grow spontaneously along fence rows and roadsides and in open field from seeds dropped by birds, producing fruits that are usually small, thin-fleshed, and dry.¹

A. POMOLOGICAL GROUPS OF SWEET CHERRIES

The varieties of the sweet cherry may be divided roughly into two pomological groups on the basis of texture of the flesh. This classification, however, does not serve to classify all varieties because many varieties have originated through hybridization and may thus have flesh characters which are intermediate in firmness.

The group of varieties known as Heart cherries in America have been called the Guigne group by French pomologists and the Gean cherries by the English. The varieties of this group have soft and tender flesh and many of them are heart-shaped. Because of the soft flesh, few of them are important commercially. The group may be subdivided into dark-colored varieties with reddish juice and light-colored varieties with colorless juice. Among the light-colored Hearts are such varieties as Coc, Ida, Elton, and Waterloo. Typical dark-colored Hearts are Black Tartarian, Early Purple, and Eagle.¹

The Bigarreau group of cherries is distinguished from the former group by having a firm, breaking flesh, although the name originally referred to the diverse colors of the fruits. These cherries are mostly roundish, though some of them are more or less heart-shaped. This group may also be subdivided on the basis of color of fruit and juice into black and light Bigarreaus. Typical

black Biggarreus are Windsor, Schmidt, and Bing, while important light Biggarreus are Yellow Spanish and Napoleon.¹

There are a number of other groups of *Prunus avium* but they are not of interest to the orchardist. The fruit grower is interested in the Mazzard cherry as a stock for cultivated varieties but the Mazzard is not, contrary to some lay opinion, a sub-division of *Prunus avium*. The name applies to any wild sweet cherry, though characteristically the fruit of the Mazzard is small and there is a relatively small amount of flesh in proportion to the pit. Thus, the sweet cherry trees that grow spontaneously in some parts of the eastern states are known as Mazzards or wild cherries and may be sources of seed for the propagation of so-called Mazzard stocks.

B. VARIETIES OF SWEET CHERRIES

Probably not more than 30 of the 549 varieties of sweet cherries described in 1914¹ are worthy of consideration for planting to supply fruit for either home use or commercial purposes in the various regions that produce cherries in North America. The list of commercial varieties to meet the needs of the several regions would likely not exceed 15.

Such varieties of sweet cherries as Napoleon, Bing, and Black Tartarian are well known in all regions that produce this fruit in commercial quantities. Philp² states that these three varieties constitute 81% of the acreage in California in 1943 and that Lambert, Republican, and Chapman accounted for an additional 12% of the acreage. Other varieties grown in limited quantities in the western states include Advance, Burbank, Centennial, Deacon, Eagle, Early Purple, Knight, and Rockport. The list of varieties grown commercially in the eastern region includes Bing, Lambert, Napoleon, Black Tartarian, Schmidt, and Windsor.

Some confusion exists in sweet cherry nomenclature because of a mixture of strains and varieties and difficulty in identifying varieties correctly. Schuster³ mentions five strains of Republican, three of Oregon, and two each of Norma, Waterhouse, Black Tartarian, Abundance, and Bing. A strain of Napoleon called Long Stemmed Royal Ann was found in California.⁴ Strains of Black Tartarian and Bing were found in Utah.⁵ More than one kind of sweet cherry is being grown in Sweden under the same name.⁶ Such is not surprising since the sweet cherry has long been known to reproduce relatively true to type when propagated from seed. It is likely, at least in some cases, that seedlings have arisen which were so nearly like certain existing varieties that they have been used to supply bud-wood for the propagation of named varieties, when in reality they were seedlings or, in a pomological sense, distinct varieties in themselves.

The more important varieties listed below are in their approximate sequence of ripening. Exact sequences are not possible for all of the varieties listed because not all of them are grown in any one location and, in some cases, two or more of them mature at essentially the same time. The arrangement indicates whether a variety is early, mid-season or late in comparison with other varieties listed.

Early Purple. It originated in Europe some 250 years ago and was introduced to America in the early part of the nineteenth century.¹ It is very early, its median ripening period being April 25 in the Sacramento Valley.⁷ The fruit is medium in size, is almost black, has a dark reddish-purple flesh, and is of high quality.¹ The flesh is too tender for shipping.⁸ The tree is a good grower,⁸ and is large, vigorous and very productive.¹ It is not recommended for California and Utah because of its low economic value.^{2,5}

Chapman, (Early Chapman). A dark red, shipping cherry of California origin^{8,9} that is supposed to be a seedling of Black Tartarian, but it is earlier and larger in size.¹ It has been one of the leading varieties for early sections in California,² but has recently declined in popularity. Fruits are very large, purplish-black, slightly tender and of very good quality.¹ Trees are large, vigorous, and upright spreading.²

Knight (Knight's Early Black). This old English variety was once very popular in England and in Eastern United States.⁸ The fruits are small to medium in size, reddish black in color, tender and of good quality. The trees are of medium size, and are very productive.¹ It is an excellent variety for home use but is not generally regarded as one of the better market varieties.

Burbank. A dark red shipping variety⁹ that originated in California where it is regarded as one of the important early sorts,⁸ though in Utah the fruit is said to be too small to warrant its recommendation for commercial planting.⁵ The trees are described as vigorous and fairly productive. The leaves are very large and the foliage is dense.²

Black Tartarian. This variety is one of the oldest, best known and most popular cherries of the Heart Type. It is enormously productive of fruits of medium size that are excellent in quality for fresh use and for canning; however, they are too soft to ship well.⁸ The fruits are purplish-black and the flesh is similar in color. The trees are large and vigorous and upright in growth habit. It is one of the six most important varieties in California² where it is regarded as an excellent pollenizer, but it is not recommended for Oregon because it blooms too early and is too soft to ship³ and in Utah it is reported as lacking in hardiness and productiveness.⁵ It is ranked next to Bing in resistance to cracking.⁹

Yellow Spanish. A very old variety of obscure European origin. The fruits are large, are bright amber-yellow with a reddish blush, have a whitish soft flesh, and are very high in quality.¹ The trees are very large, vigorous and productive¹ and are hardier in bud and wood than the average variety.^{5,9} It is useful for dessert and is satisfactory for canning when a white variety is desired, though the fruits are smaller and softer than Napoleon.⁵

Schmidt (Schmidt's Bigarreau). The fruits are very large, are purplish-black with purplish-red flesh, are firm and meaty, and have very good quality for both dessert and canning.^{1,10} The trees are vigorous and moderately productive and the variety is one of the most profitable for the northeastern states⁵ though in Utah it is said to be unproductive³ and it is not an important variety in the Pacific Coast states.^{2,3,7}

Napoleon (Royal Ann.) This variety is generally known and marketed as Royal Ann in the Pacific Coast states where it constituted about 40% of the total production of sweet cherries from 1939 to 1943. It is the leading, light-colored, firm-fleshed cherry in all areas that produce sweet cherries,



Figure 6. Typical Black Tartarian tree 17 years old on left and Bing tree about 25 years old on right, illustrating upright and spreading growth habits. (Courtesy of California Experiment Station.)

and it is the most important variety for canning and for brining.² The variety is of unknown European origin and is probably about three centuries old though it was not given its present name until 1820.¹ The fruits are large and handsome, having varying shades of red over a yellowish background and a whitish flesh with colorless juice.¹ The trees are large, vigorous and very productive.¹ It ranks between Bing and Lambert in susceptibility to cracking.¹¹

Bing. A large, firm fleshed, reddish-black cherry¹⁰ of the Bigarreau type originating in Oregon in 1875.¹ It is excellent in quality and is regarded as one of the best varieties for shipping.⁸ It is highly flavored, aromatic,

and delectable.¹⁰ It ranks second among all varieties and first among the dark cherries grown in California and is one of the leading varieties in all areas producing sweet cherries, though it is rather susceptible to winter injury in Michigan. It is rather resistant to cracking in Michigan¹¹ and California⁹ but is more susceptible than either Lambert or Napoleon in the Northwest.¹¹ It rates only fair for freezing.¹²

Deacon. A variety of the Bing type but slightly smaller and more sprightly. It is excellent for canning, is a good shipper, and is a good cropper. It is regarded as one of the best pollenizers for other varieties in the Northwest since it is a better market variety than other good pollenizers like Black Tartarian and Republican.³

Republican (Black Republican). A dark red shipping variety of American origin.⁹ The fruits are medium in size, have a purplish-red, rather firm flesh and are of good quality. The trees are large, vigorous and very productive.¹ Production is limited mostly to the Pacific Coast states where it is a recommended pollenizer in the Northwest³ and one of the six most important varieties in California.³ It is rated as satisfactory for freezing.¹²

Lambert. The fruits of this variety are very large and are dark red to reddish-black with a dark red, firm pleasantly flavored flesh of excellent quality.⁷ It is grown generally but is in most favor in the Pacific Northwest, where it had its origin. The variety is not as important in California because it cannot compete successfully with varieties being shipped from Oregon and Washington at the time of its maturity in the former area. The trees are vigorous and productive.⁸ The fruit is less susceptible to cracking than Bing or Napoleon in the Northwest¹¹ but is likely to crack badly in the eastern states^{10,13} and in California.² It is rated as fair for freezing.¹²

Windsor. This is a large almost black, firm-fleshed, high quality variety of the Bigarreau type that originated in Ontario, Canada.⁸ The flesh is light-red with reddish juice.¹ The trees are hardier in bud and wood than those of the average variety⁹ and are very productive.⁸ It is regarded as one of the best varieties for New York, Michigan, and Ontario where most of the production is located.⁸ It is regarded as fair for freezing.¹²

3. The Red Cherry

The trees of the red or sour cherry, *Prunus cerasus*, are 20 to 30 feet high, open-headed, round topped or spreading and often without a central leader. The branches are spreading, slender and more or less drooping, while the branchlets are slender, willowy and reddish-brown. The fruit is roundish-oblate or cordate with slightly compressed sides and averages about three-fourths inches in diameter. The leaves are much smaller, darker green in color and more numerous than those of the sweet cherry.

The red cherry is found in a truly wild condition in southwest

Asia and southeast Europe and is a frequent escape from cultivation. Suckers spring freely from the roots. The trees are shorter lived than those of the sweet cherry.¹

The commonly cultivated varieties of the red cherry are about as hardy as the Northern Spy apple but some Russian varieties may be as hardy as the McIntosh apple and might therefore be used to extend the growing area to higher latitudes.⁹

A. POMOLOGICAL GROUPS OF RED CHERRIES

The cultivated varieties of the red cherry may be divided into two distinct groups on the basis of the color of the juice in the fruits.

Red cherries having a colorless juice are known generally as the Armarelles though the British often designate them as Kentish cherries and the French as Cerisier Commun. They are pale red fruits, more or less flattened at the ends. Despite the name, the varieties of this group have less bitterness and are less acid than the darker colored cherries and are therefore more suitable for eating out of hand. Early Richmond and Montmorency are the better known representative varieties of this group.¹

Varieties that are very dark in color and have a reddish juice are known generally as Morellos, though the French call them Griottes. The trees are usually smaller, bushier and more compact than those of the Armarelles and have branches that are more horizontal, or even drooping. Fruits are more spherical or cordate in shape than those of the Armarelles. Typical varieties of this group are English Morello, Ostheim, Olivet, and Brüsseler Braune.¹

Cherries of the Morello group are hardier in bud and in nearly opened flowers than varieties of the Armarelles. On the other hand, the Armarelle cherries withstand high summer temperatures.¹⁴

The Marasca cherry, from which is made a distilled liqueur known as maraschino, constitutes a third group of *Prunus cerasus*. This cherry is a native of the former Austrian province of Dalmatia, now Yugoslavia, where it grows wild and is cultivated to a limited extent. The trees have great vigor and compact inflorescence. The fruits are small and almost black and have an intensely red flesh and juice. The fruits are very acid and have a bitterness that gives the characteristic flavor to the maraschino distilled from them.¹

Some botanists have classified the above three groups of cherries into three distinct species and some have listed them as botanical varieties *Prunus cerasus*.

B. VARIETIES OF RED CHERRIES

Of the 270 named varieties of the red cherry, the few commercial varieties are much more generally grown than are the better varieties of sweet cherries.¹

There are only three varieties of red cherries grown in appreciable quantities in North America, all of which are of European origin. Their descriptions follow in the order of ripening.

Early Richmond (Kentish). This is one of the oldest and most widely distributed varieties of red cherries.⁸ The fruit is of medium size, light red changing to dark red, pale yellow flesh with light pinkish juice and sprightly and pleasantly flavored.¹ It is of mediocre quality and not as desirable for canning or for freezing as Montmorency. The trees are medium in size, medium to below in productivity and relatively hardy. It is valuable as an early variety to lengthen the season for red cherries.

Montmorency. This is the leading and most profitable red cherry for the fresh fruit market and for canning and freezing. The fruits are medium to large in size, light to dark red in color with a pale yellow flesh and abundant light pink juice.¹ The quality is excellent and the firm flesh enables it to withstand the handling essential to preparation for processing. The long harvest season plays no small part in accounting for its popularity. The large trees are vigorous, very productive, hardy and healthy.

English Morello. This variety is considered the best of the Morello group and it is the best of the late varieties of red cherries. The fruits of this very old variety are medium to below medium in size, dark red to almost black in color, and the flesh is dark red and contains a dark colored juice. They are tart and good in quality. The fruits will hang on the trees long after they are ripe. The trees are small and round topped and are likely to become more or less dwarfed from over-production.¹ The laterals on the mature trees are often drooping and make only short annual growths resulting in fruiting at the tips of long, barren branches. It is a good variety to prolong the harvest season for both processing and shipping.

There is not the apparent varietal mixture among red cherries that seems to exist in sweet cherries but the varieties of the former produce bud mutations rather abundantly.¹⁵ These mutations are in many directions but those sporting in the direction of unproductiveness in the Montmorency variety are of greater importance than those sporting in the direction of desirable characteristics because growers fail to note or mark trees that are unproductive and do not realize that they are consistently and regularly light producers for one or more reasons given. Among other mutations of rather frequent occurrence are strains of Montmorency, English Morello, and Early Richmond in the direction of season of ripening and strains that possess different degrees of resistance or susceptibility to the virus that causes cherry yellows.^{16,17}

Selection is necessary to fix the type in bud mutations because the majority of these mutations of the Montmorency cherry are sig-

nificantly more variable than their parent clones. Reversions and segregates are of frequent occurrence among mutations when they are propagated vegetatively.¹⁸

4. The Duke Cherries

The Duke cherries were formerly regarded as a botanical variety of *Prunus avium* but they are hybrids between *Prunus avium* and *Prunus cerasus*. All gradations between the two species may be found among the recognized varieties, but, in general, they resemble *Prunus avium* more closely than *Prunus cerasus*. The trees range in growth habits from the May Duke, which resembles the sweet cherry trees, to those which look much like the red varieties.¹

The Duke cherries are tetraploids, having a chromosome number of 32, while the chromosome numbers for sweet and red cherries are 16 and 32, respectively.^{9,19,20} It might be expected that a hybrid between two species having chromosome numbers of 16 and 32 would be a triploid ($16 + 8 = 24$), but such is not the case.

Most of the pollen grains of Duke cherries are sterile and the seeds of several varieties are sterile.¹ Much of the sterility results from irregularity in chromosome distribution at meiosis.¹⁹

The word Duke is a corruption of Medoc, a district in Gironde Province of France. The French call this group of cherries Royale while the English and Americans designate them as Dukes.

Sixty-five varieties of Duke cherries were described in 1914,¹ but of this number only four of these are worthy of discussion here.

May Duke. This is one of the oldest and best known cherries. It probably originated in France more than 250 years ago. The fruit matures early but unevenly. The fruit is medium to below medium in size, dark red at full maturity and the flesh is medium to dark red with pinkish juice. They are tender, juicy, sprightly, and very good in quality. The trees are upright and very productive.¹ The trees are as hardy as the Armarelles.¹⁴ The variety yields an excellent frozen product. They are grown chiefly for home use and local market.

Royal Duke. A variety closely resembling May Duke except that it is later in ripening and the fruits are larger and a little lighter in color. It apparently had its origin in Europe some 150 years ago. The flesh is pale yellowish-white with a tinge of red and the juice is pinkish. The fruits are tender, sprightly, pleasantly acid, and very good in quality.¹

Reine Hortense. A high quality variety of French origin that possesses both the refreshing acidity of the red cherry and the richness of the sweet cherry. The fruits mature in mid-season. The handsome fruits are uniformly large,

round, and bright glossy red. The fruit does not stand handling and shipping as well as some of the other varieties of the group. The trees are medium in size, upright spreading in growth habit, and moderately productive in comparison with other varieties of Dukes.¹

Late Duke. This variety is a variant of May Duke that ripens two weeks to a month later. It is also an old variety of European origin. The fruits are medium in size, dark red and have an amber-colored flesh and abundant juice. They are tender, sprightly sub-acid and excellent in quality. The trees are vigorous, upright spreading and moderately productive.¹

5. Minor Species

A few other species deserve brief mention because they are used as stocks upon which to bud or graft varieties of *Prunus avium* and *Prunus cerasus* are grown in some regions to supply fruit, or are hybridized with other species to provide fruits better adapted to certain regions in which the varieties of the two better known species cannot be grown successfully.

The Mahaleb Cherry. Most of the cultivated cherries are grown on either Mazzard or Mahaleb stocks. The merits of each will be discussed in another chapter. The Mahaleb cherry belongs to *Prunus mahaleb*, which is a small, bush-like tree that grows wild in southern and central Europe and eastward to Turkestan and is an escape from cultivation in parts of eastern North America. The trees seldom attain the height of even a small tree. The very small fruit is borne in small clusters and is black at maturity and too hard and bitter to be edible.¹⁰

The seed used for propagation in America is produced mostly by the wild trees in France and Italy. There are several horticultural varieties of the Mahaleb cherry valuable as ornamentals. The wood is favored for cabinet making, and the odoriferous leaves are used in France in the manufacture of perfumes and in cooking to give savor to sauces.¹ The fruit may also be used for making pies.

Prunus tomentosa is grown in China and Japan for both its fruit and as an ornamental. The trees are vigorous, dome topped, hardy and bush-like, attaining heights of 10 to 12 feet. The fruit is about one-half inch in diameter, roundish, currant-red and tender and the flesh is light red, juicy, stringy, melting, sprightly, sour and good in quality.¹

The sand cherry or dwarf cherry of eastern North America is classified as *Prunus pumila*. It is a small, weak growing, hardy shrub that produces two to five flowers in an umbel and nearly round, pendulous, purple-black fruits nearly one-half inch in diameter. These fruits are sour and astringent. It is found on rocky and sandy inland shores from Maine to the District of Columbia and northwestward to the Lake of Woods in Canada. Since it grows wild on the sand dunes of the Great Lakes, it may have possible use in arid regions. There are no named varieties for fruit growers.¹

The western sand cherry, *Prunus besseyi*, is a close relative of the sand

cherry of eastern North America. It is a small, hardy shrub whose habitat extends from Manitoba and Minnesota to southern Kansas and westward to Montana, Wyoming and Utah. The plants are very productive and withstand the exacting climates in which it grows. The fruit from plants of this species are more than one-half inch in diameter, globular in shape and yellowish, mottled or purplish-black in color. The flesh of the wild fruits is tender and juicy and varies in flavor.¹

The pioneers used the wild fruit for sauces, pies and preserves and sometimes for eating out of hand. A considerable number of varieties of the species are cultivated and hybrids between this species and at least seven species of plums, the sweet cherry, the peach and the apricot are grown as named varieties. Many of these hybrids are valuable varieties for home use and local markets in the northern Mississippi Valley and the plains to the west.

Prunus besseyi has been used as a hardy stock for the peach, the apricot, and native plums where winter cold limits the use of better stocks. It is not satisfactory for the true cherries.¹

Some fruit of *Prunus pseudocerasus* is shipped for very early market. The fruit is smaller than the red cherry, mildly sub-acid and somewhat insipid. The buds require little chilling so it should grow and fruit well in all parts of California. Little is known about its resistance to cold.⁹ This species is a well-known ornamental in all parts of the world and it is used as a stock for cherries in Japan.¹ It is rare in America and little is known regarding its possibilities.

Prunus pennsylvanica is known as the bird, the pin or the pigeon cherry. Its habitat extends from the Atlantic Coast to the eastern slopes of the Coast Range in northern United States and southern Canada. It has been used as a stock for red cherries in some of the colder regions of North America and it is doubtful if it should be recommended except for such regions. It suckers badly and dwarfs the trees growing on it.¹⁰ It did not prove successful in the Grand Traverse Region of Michigan as a stock.

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DEVELOPMENT AND STRUCTURE OF THE FRUIT

1. Flower Buds

A bud may be defined as "an incipient or unelongated branch or the free extremity of a branch."¹ It may be the tip or growing point of an elongating shoot or it may be in a resting stage. In the case of the cherry, either embryonic leaves or flowers are borne on a very short axis that is protected by outer whorls of scales.

Classes of Buds. A bud containing an axis that bears unexpanded leaves and the primordia of buds in their axils, and at the apex, is known as a *leaf bud*. A bud that contains the unexpanded, essential parts of flowers is generally designated as a *flower* or *fruit bud*. Since the flower bud of the cherry does not contain both unexpanded leaves and flowers, as is the case with flower buds of the apple, it is known as a *simple flower bud*.

Buds may be *lateral* or *axillary* or they may be *terminal* in respect to location. Axillary buds are borne in the axils of leaves and laterally along the sides of branches of varying lengths, while terminal buds occur at the terminal ends of branches. Flower buds of the cherry are almost always axillary and leaf buds are either terminal or axillary.

A layman may distinguish between flower buds and leaf buds of the cherry by their location and by differences in shape (Figure 7). The leaf buds usually are more acutely pointed and are more slender than flower buds. Leaf buds are located terminally on very short growths called spurs or on shoots of varying lengths. They may also be axillary in location. Flower buds are usually located laterally on both spurs and shoots. Thus, terminal buds are nearly always leaf buds while axillary buds on shoots may be either leaf or flower buds.

Differentiation of Flower Buds. Buds that unfold in the spring are formed early in the previous growing season. It is not possible to determine whether a bud will become a flower bud or a leaf bud, except



Figure 7. The terminal buds of shoots and spurs of the red cherry usually are leaf buds; the lateral buds of shoots may be either fruit buds or leaf buds, while those of spurs are fruit buds. Leaf buds are more acutely pointed and are more slender than flower buds.

possibly by location on the shoot or spur, until microscopic examination of the axis reveals an elevation of the crown that is broadly rounded at the apex. This is accompanied by the development of fibrovascular bundles and pith areas advancing concurrently. The crown soon becomes slightly irregular or papillated by the organization of new axes which give rise to individual floral parts.^{1,2}

The first indications of flower parts of buds of the King Armarelle variety were identified in Wisconsin early in July of both 1899 and 1900.^{3,4} In early June, the bud scales were few in number and the core or axis was very small. Development continued throughout the summer until early November. Unmistakable flowers were recognized in mid-summer. Thus, flower development in the buds began while the

fruit was maturing. All flowers of a cherry bud developed at the same rate.

The first signs of differentiation of flower buds in the Louis Philippe variety were noted on June 30 during 1909 in Virginia, and blossom primordia of the sweet cherry were reported to be visible during July at Heidelberg, Germany.²

Tufts and Morrow³ found the first evidences of differentiation in Early Richmond July 12 and in Napoleon July 3. They report that in California the sepal and petal primordia of Early Richmond buds were plainly visible by August 10 and that the early stages of stamen and pistil formation were evident about September 1. Napoleon buds reached these stages of development some 10 days earlier. All flower parts of both varieties had assumed final form by the end of September.

The rate at which fruit buds develop may be affected by the age and vigor of the trees. Buds at very strongly growing points and those on trees weakened by partial defoliation are retarded in their development. Thus, the buds on younger, stronger growing trees usually are less advanced than those on older, healthy trees.⁶

Practically no changes take place within buds during winter in the colder climates but development is revived about the time that spring temperatures favor activity in other portions of the tree.^{2,3}

2. The Flower

Inflorescence. The fruit or flower bud opens in the spring to produce a cluster of flowers. Each flower of the cluster is supported by a stem or *pedicle* and these, in turn, are borne on a common stem or *peduncle*. The arrangement of the flowers on the peduncle is termed the *inflorescence*. The flowers of the cherry are closely crowded on a very short peduncle and the pedicles are nearly equal in length. Such an arrangement is known as a *fascicle*. The cluster of flowers of the cherry is flat-topped or slightly convex and the flowers at the base of the cluster open first, forming a cluster designated as a *corymb*. Thus, the cherry flowers are in fascicles of a corymbose type of inflorescence.^{1,7}

Flower Structure. The flower consists of *calyx*, *corolla*, *stamens* and *carpels* (Figure 8). The calyx is a whorl of floral leaves or *sepals*. The set of floral leaves above the calyx is the corolla, each leaf of which is a *petal*. Within and above the corolla is a third whorl known as the *androecium*, the separate parts of which are stamens. Each stamen

consists of an *anther* and its supporting, thread-like stalk called the *filament*. Within the anther is formed the male fertilizing element known as *pollen*. The center-most part of a cherry flower is a simple *gynoecium* or pistil, consisting of the swollen basal portion or ovary, the slender stalk or style, and the expanded tip of the style or *stigma*. The ovary of the cherry flower contains a single *carpel* and two *ovules*, only one of which usually develops into a seed.⁷

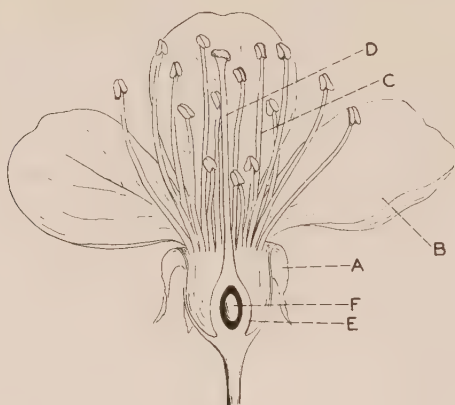


Figure 8. A longitudinal section of a flower of the Montmorency variety. The sepals, petals, and stamens arise from the rim of a cup-like receptacle. A: sepal; B: petal; C: stamen; D: pistil; E: ovary; F: carpel.

The hollow or concave cup-like structure of the cherry flower that supports the calyx, corolla, and stamens on its rim is known as the *receptacle*. The ovary, is located at the bottom of this cup-like receptacle. Flowers with such arrangements are *perigynous*.

Inasmuch as both stamens and a pistil are present in the same cherry flower, the flowers are *perfect*, bisexual, or hermaphroditic.⁷

Pollination is the transfer of pollen from the anther to the stigma of the pistil. The pollen grains may then germinate on the moist surface of the stigma, forming pollen-tubes that grow through the style to permit the fusion of the contents of the pollen-cell with the egg-cell of the ovule. The completion of this process is *fertilization*.

Shortly after full-bloom the floral parts dry or wither to form a *shuck*. This shuck is shed in a few days, leaving the carpel to develop as a fruit.

3. Fruit Development

The cherry fruit develops from a single carpel and may therefore be defined as an enlarged or mature carpel or ovary. The cherry and other stone fruits are classified as *simple* fruits in contrast to other kinds of fruits that have several or many carpels developing from the same flower (apple, raspberry, strawberry).

The seed is essentially an embryo and associated parts. It is the direct result of fertilization, possessing genes of both the pollen parent and the female parent. The surrounding tissues are, however, a part of the mother plant and, being vegetative, are not altered in size, shape, color, or flavor by the pollen parent.

The walls of the mature ovary or the tissues surrounding the seeds of the cherry are called the *pericarp*. The pericarp consists of three distinct regions or layers; the inner hard, stony layer that becomes the pit is the *endocarp*; the thick fleshy or edible middle layer is the *mesocarp*, and the outer thin layer of "skin" is the *exocarp* or *epicarp*.

Tukey and Young⁸ employ a different terminology to the principle tissues of the pericarp or ovary wall (Figure 11). They designate the pit (endocarp) as "stony pericarp" and the flesh as "fleshy pericarp." They further divide the stony pericarp into an inner layer and an outer layer. The fleshy pericarp is divided into an innermost layer of small thin-walled cells adjacent to the pit, a middle layer of large parenchymous cells, and an outer layer of collenchymous cells. The outermost layer of cells of the fruit is called the outer epidermis. This outer epidermis and the hypodermal layer constitute what is generally known as the exocarp or epicarp.

A. DEVELOPMENT OF THE SEED

The development of the embryo for the Downer variety of sweet cherry in New York for a period beginning 55 days before full bloom and extending to full ripeness of the fruit is diagramed in Figure 9. The development for red and sweet cherries is similar,^{9,10}

The ovary and its two ovules parallel each other in making a slight increase in growth during the first 41 days of the period under consideration. During the ensuing 14 days, until full bloom, the ovary and the nucellus and integuments enlarge rapidly. The megaspore mother cell is formed at the beginning of this period and the megagametophyte is in turn formed from it three to seven days before full bloom. One of the two ovules is arrested abruptly in development two

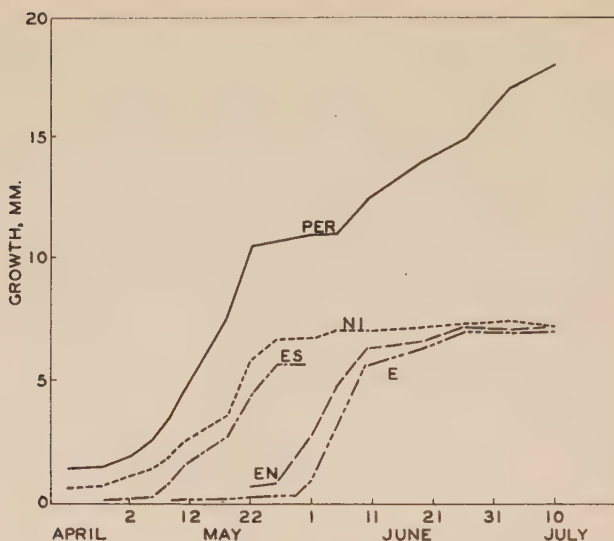


Figure 9. Early development of pericarp (PER), nucellus and integuments (NI), megagametophyte and embryo sac (ES), endosperm (EN), and embryo (E) of a late ripening variety of sweet cherry (Downer) which produces a high proportion of viable seed. (After Tukey.¹⁰)

to seven days before full bloom. The other ovule assumes the ascendancy.

A sudden acceleration in the growth of the ovary, nucellus and integuments, megagametophyte, and embryo sac follows the time of fertilization, lasting for a period of 17 days. This acceleration in growth rate, however, is not the result of fertilization even though it is more or less coincident with it. The nucellus and integuments attain approximately 80% of their ultimate size during this period. On the other hand, the embryo and endosperm make no appreciable growth during the 17 days.

The 17th to the 31st days following full bloom constitute a period during which the pericarp is very much retarded in development, accompanied by a sudden acceleration in the growth rates of the endosperm and the embryo. Newly formed cells of the endosperm enlarge and, in turn, are digested by the rapidly growing embryo.

The second period of rapid enlargement of the pericarp begins 31 days after full bloom and continues until the fruit is full ripe. The

nucellus and integuments attain maximum size during this period and the endosperm and embryo continue development, but at a slower rate than prevailed during the preceding period. Finally, the ripe fruit contains a viable seed consisting of an embryo with two well developed cotyledons, surrounded by a thin layer of endosperm and a fine line of nucellar tissue, all of which completely fill the integuments.¹⁰

The ovary of an early ripening variety of sweet cherry (Early Purple) develops in a manner similar to that just presented for a late variety until 17 days after full bloom. The period of retarded pericarp development for the early variety was six days shorter than that for the late cherry. The final period of rapid pericarp development was 37 and 66 days, respectively, for the early and late varieties. While the development of the embryo and endosperm was regular and uniform during this final period for the late variety, it was suddenly checked at varying degrees of development in the early cherry and a viable seed rarely was produced. The nucellus and integuments collapse to give a shriveled seed in contrast to plump ones that are viable.¹⁰

B. EMBRYO ABORTION

Abortive embryos are frequently associated with the dropping of fruits because of sterility, incompatibility, poor pollination, or nutritional deficiencies. The abortive process may be initiated before full bloom or at any time thereafter. It may result in the premature dropping of the fruits in any one of three distinct waves of dropping or the fruit may reach full ripeness even though the seed is not viable.

Bradbury⁹ collected pistils of the Montmorency variety before full bloom that showed some degenerate megagametophytes. Many of the abortive pistils examined had been pollinated and the pollen tubes had usually reached the ovarian cavity where they grew at random through the upper portion of the cavity. Both of the ovules had shriveled in such cases. These fruits usually were shed during the first wave of dropping. Many of the aborting fruits dropping during the second wave had degenerate embryos and endosperms and in many of the others the entire contents of the embryo sac were disorganized. She suggests that unfavorable nutritional conditions may be responsible for the first wave of dropping and that they may play a part in the second and third periods of dropping.

Gray,¹¹ working with the same variety, concluded that there is some abortion within the embryo before the period of full bloom and

stated that it is not known whether this early abortion is due to weather, nutrition, or genetic constitution. Such early abortion of the embryo causes the fruits to be shed in the first wave of dropping.

Embryo abortion may occur in early ripening varieties of the sweet cherry as late as 12 days prior to the ripening of the fruit.¹⁰ A sudden arrest in the development of the embryo accompanies abortion. The nucellus collapses and the integuments shrivel at this time and disintegration of the aborted embryo may begin in five days after arrested development or it may remain intact for as much as 42 days.

Tukey¹⁰ removed the aborting embryos from fruits and cultured them artificially, proving that they were not structurally abnormal and indicating that lack of proper nutritive conditions is responsible for the failure of early ripening varieties of the sweet cherry to produce seed. Lilleland and Newsome¹² reached similar conclusions. They state that the very short maturation period of early varieties of sweet cherries results in a kernel low in fat, and, in consequence, a nutritionally deficient embryo. They assume this to be the result of food competition and the early maturity of the flesh.

Tukey¹³ destroyed embryos at various stages of development to determine whether embryo abortion is due to the initiation of rapid development of early ripening varieties or if abortion brings about rapid development of the pericarp. The embryos were destroyed on the same date in Early Richmond, Montmorency, and English Morello varieties. The Early Richmond fruits were just entering the final stage of rapid pericarp development and those of the other varieties were at that stage when the pericarp is undergoing a slow rate of enlargement while the embryo is developing rapidly.

Destruction of the embryo of the Early Richmond fruits resulted in early ripening of otherwise normal fruits while injury to the embryos of the other two varieties abruptly checked fruit development and resulted in abscission of the fruits. These responses indicate that abortion of the embryo is the factor which effects pericarp enlargement rather than the reverse. Tukey concluded that early ripening of some varieties is due, at least in part, to abortion of the embryo.

C. DEVELOPMENT OF THE PERICARP

Tukey¹⁴ designated the growth periods as Stages I, II, and III. Stage I is that period of rapid increase in size of the pericarp immediately following fertilization. Stage II is a period of retarded pericarp

development occurring more or less mid-way between full bloom and full ripeness of the fruit. Stage III is the second and final period of rapid increase in size of fruit. Figure 10 shows the duration of each period for three varieties in New York in 1934 and shows the growth curves for the pericarp, the nucellus and integuments, and the embryo.

Stage I is of nearly identical duration for all varieties. The period is characterized by arrested embryo development and rapid growth of both the nucellus and integuments and the pericarp. The nucellus and integuments reach full size by the end of this period. The transition from Stage I to Stage II is abrupt for each of the three varieties. At this time the stony endocarp begins to harden. The duration of Stage II is correlated directly with the season of fruit ripening, ranging from five days for Early Richmond to 28 days for the late ripening English Morello. The embryo begins a period of rapid development at the initiation of this stage of retarded development of the pericarp, and reaches maximum size in 18 to 25 days in each of the varieties. Stage III is similar in length for all three varieties and continues until the fruit is ripe.

A summary of the histological and structural changes in the developing fruit of the Montmorency cherry from a period beginning 18 days before full bloom to full maturity of the fruit follows:⁸

Stony Pericarp. The stony pericarp or endocarp consists of a single row of epidermal cells, called the inner epidermis, and three or four layers of cells of the pericarp at the stage of development attained 18 days before full bloom (Figures 11 and 12). The cells of the portion that becomes hard and stony are smaller than adjoining ones. The inner epidermal cells elongate tangentially and divide transversely just before full bloom (Figure 12*B*). The cells nearly treble in number before full bloom and their diameters increase somewhat. At full bloom the inner stony pericarp is four cells thick and the outer portion is about 10 cells thick.

The wall of the stony pericarp increases in thickness approximately five times, by both increase in number and size of cells, during Stage I (Figure 12*D*). However, no cell division occurs in the inner stony pericarp during the latter half of Stage I, whereas most of the increase in numbers of cells of the outer portion takes place during this half of the period. The cell walls thicken during Stage I but no appreciable hardening occurs.

During Stage II (Figure 12*F*), the cell walls thicken and harden

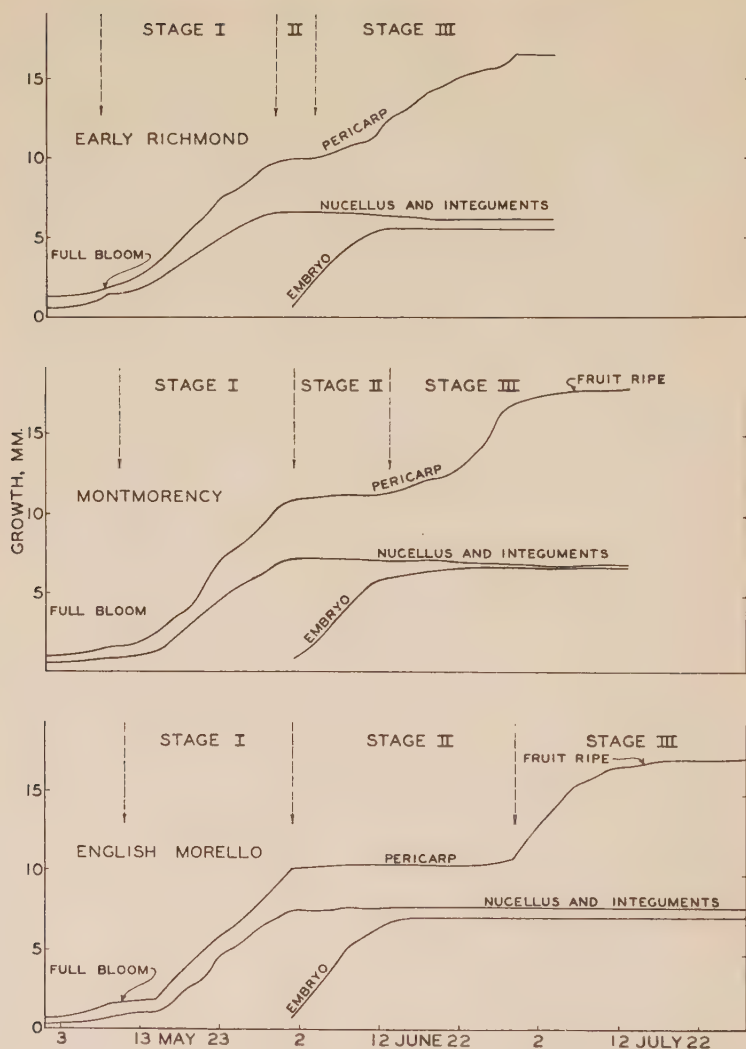


Figure 10. Growth curves of pericarp, nucellus and integuments and embryo of three varieties of red cherry ripening at different seasons. Note the nearly identical time of abrupt change from arrested to rapid embryo increase (represented by lines) for all varieties independent of the season of ripening. The main difference in early and late ripening varieties is in the length of the period of arrested development of the pericarp. (After Tukey.¹⁴)

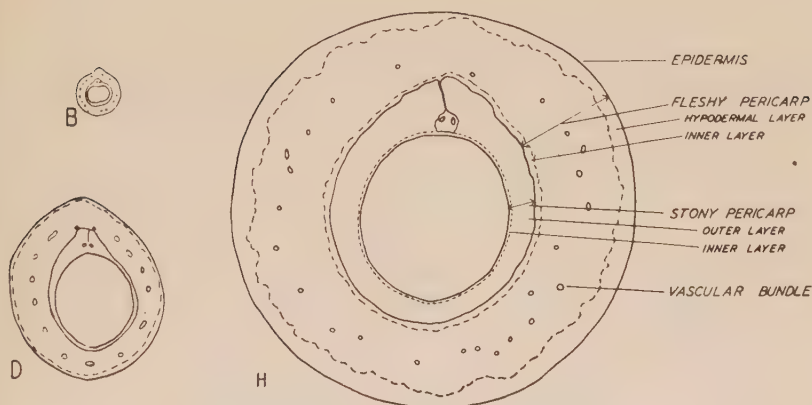


Figure 11. Development of the fruit of the Montmorency cherry as seen in transverse section. *B*: six days before full bloom; *D*: 11 days after full bloom (Stage I); *H*: 40 days after full bloom (Stage III). (After Tukey and Young.⁸)

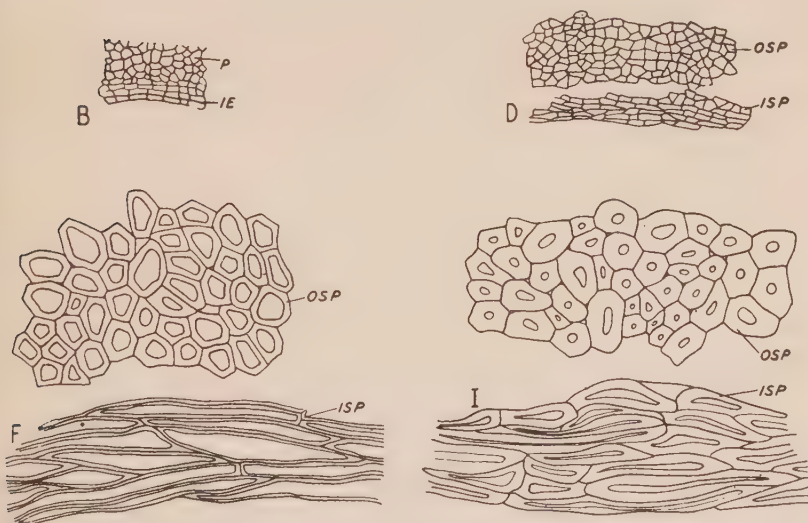


Figure 12. Development of the stony pericarp as seen in transverse section. *B*: six days before full bloom; *D*: 11 days after full bloom; *F*: 26 days after full bloom; *I*: fruit ripening, 57 days after full bloom. (After Tukey and Young.⁸)

but some cell division takes place in some parts of the stone pericarp. This portion of the pericarp consists of 26 to 27 layers of very thick walled, lignified cells at the end of this stage and is less than one-half the total thickness of the pericarp. No cell division was observed beyond the middle of Stage II, but the cells were living.

The stony pericarp increases in hardness and brittleness during Stage III (Figure 12I). Most of the cells are matured as schlerenchyma and only a few of them are living.

Fleshy Pericarp. The cells of the fleshy pericarp (Figures 11 and 13) are isodiametric and parenchymatous 18 days before full

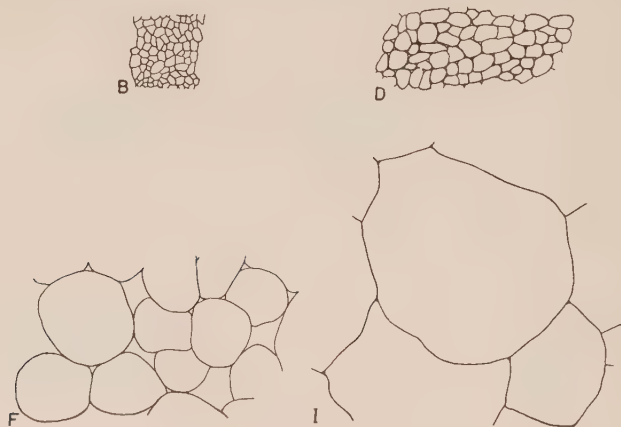


Figure 13. Development of the fleshy pericarp in the region between the hypodermal layer and the ring of vascular bundles. *B*: six days before full bloom; *D*: 11 days after full bloom; *F*: 26 days after full bloom; *I*: fruit ripening. (After Tukey and Young.⁸)

bloom. Increase in thickness of the layer prior to full bloom is due mostly to cell division.

The number of cell layers increases some 20 to 30% and cell diameters quadruple during Stage I (Figure 13D). Intercellular spaces become numerous and prominent by the end of the period. A hypodermal layer, five or six layers of the thick walled cells, is differentiated during State I. The fleshy pericarp increases in thickness about seven times during this period.

The fleshy pericarp increases only six percent in thickness during Stage II (Figure 13F). Some cell enlargement occurs and there is

some cell division in the layer of small cells next to the stony pericarp.

Four divisions of tissues are recognizable during Stage III (Figure 13*I*), the period of final swell: (1) a hypodermal layer of collenchyma, elongated tangentially, (2) a peripheral layer of thin walled roundish, oval parenchyma, extending from the hypodermal layer to just inside the ring of vascular bundles, (3) a layer radially elongated cells extending nearly to the pit, and (4) a thin layer of small isodiametric cells adjacent to the pit. There is a gradual transition from one of these layers to the adjoining ones.

The chief feature of Stage III is cell enlargement (Figure 13), some of which become 25 times the diameters observed at full bloom. Those in the hypodermal layer enlarge tangentially as do epidermal cells, but as the stony pericarp is approached, the cells become roundish oval, nearly round, and then radially elongated. Intercellular spaces become less conspicuous and cell walls become thinner during Stage III due to stretching. Some 27 to 29 layers of cells are observable.

Vascular Bundles. A ring of 18 to 20 vascular bundles, paralleling the central axis of the fruit may be found in a cross section (Figure 11). They are differentiated as early as 18 days before full bloom, but they are not conspicuous until full bloom. There is no increase in number of bundles as the fruit develops. The system extends throughout the tissue by transverse branching from the main bundles and finally it ramifies through all of the fleshy pericarp.

Epidermis. The outer epidermis (Figures 11 and 14) is a single

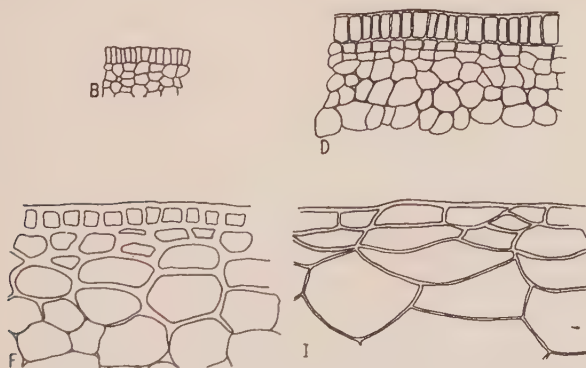


Figure 14. Development of the epidermis and the hypodermal layer in transverse section, *B*: six days before full bloom; *D*: 11 days after full bloom; *F*: 26 days after full bloom; *I*: fruit ripening. (After Tukey and Young.⁸)

layer of cells covered externally by continuous cutin, except as interrupted by stomata. The radially elongated cells of this layer are well differentiated 18 days before full bloom. They increase in both number and size prior to full bloom.

The number of cells in the epidermal layer more than doubles during the first 10 days of Stage I, and then cell division ceases. The cells enlarge both radially and tangentially, though most enlargement takes place toward the end of the period. The cuticle attains nearly full thickness during the latter part of Stage I (Figure 14*D*).

There is no cell division during Stage II but there is some tangential elongation and the walls thicken considerably (Figure 14*F*). Great enlargement in a tangential direction, accompanying the large surface increase of the fruit, takes place in Stage III. There is also a slight increase in cuticle thickness during this period. The epidermal cells of ripe fruits are well supplied with chromoplasts that give the fruits a bright red color.

Stomata. The stomata are fully differentiated 18 days before full bloom. They are unevenly distributed over the surface of the fruit, being numerous near the apex and few in number near the stem end of the cherry. There are no chromoplasts in either the guard cells or adjacent cells. The contents are yellowish or straw-colored, giving the appearance of dots. These stomata do not form lenticels as in the case with some other tree fruits; they are still intact in ripe fruit unless ruptured mechanically or by sprays.

D. GROWTH CURVE

The three stages of development are readily noted in Figure 15: rapid development following fertilization is Stage I; a mid-season period of delayed fruit development for Stage II, and a period of very rapid enlargement represents Stage III.

During Stage I, Early Richmond fruits increased their size by approximately 20,000% and the increases for Montmorency and English Morello were nearly 30,000 and 23,000%, respectively. They attained approximately 18 to 23% of their ultimate sizes during Stage I.

Very little fruit enlargement occurred during Stage II for Early Richmond and Montmorency. The English Morello fruits, however, made some increase in growth during the latter part of Stage II.

The increases in size of fruits preceding full ripeness amounted

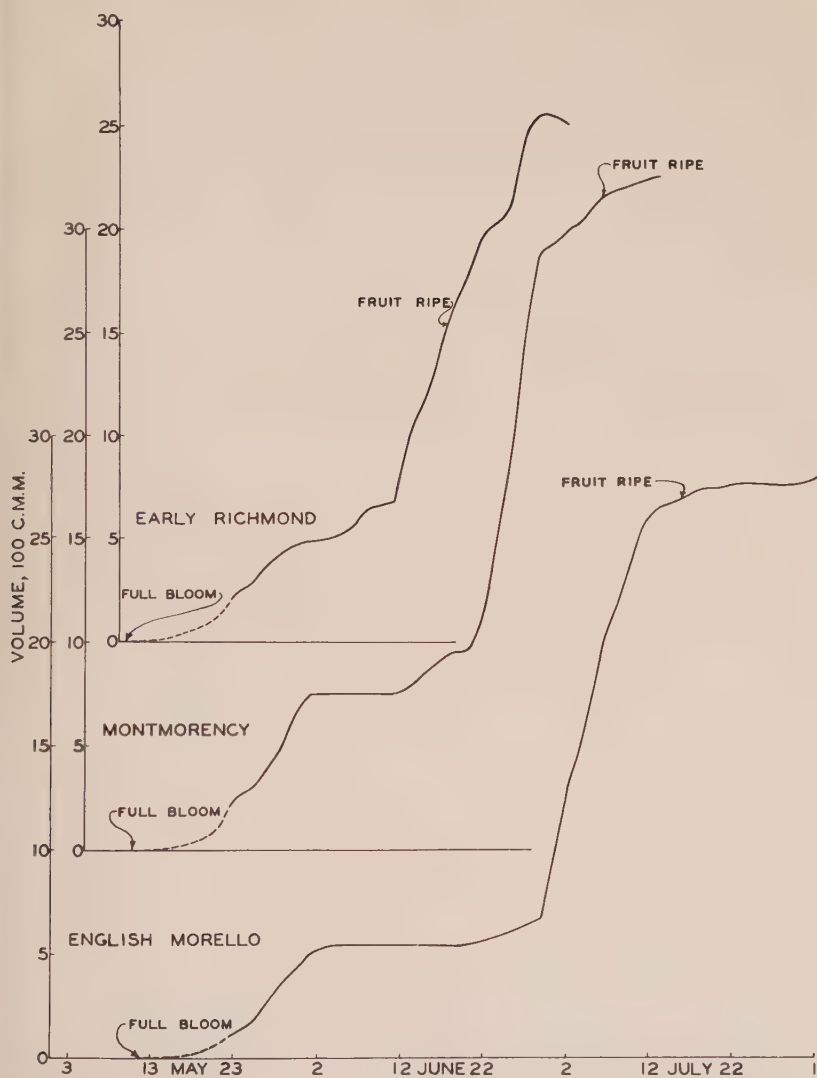


Figure 15. Volume increase of Early Richmond, Montmorency, and English Morello cherries. (After Tukey.¹⁴)

to 214% in 14 days for Early Richmond, 296% in 25 days for Montmorency, and 299% in 17 days for English Morello. The fruits of Early Richmond continued to increase rapidly in size for nine days after the fruit ripened and then there was a slight decline in size. Montmorency fruits completed the period of most rapid enlargement four or five days before full ripeness but continued to increase in volume at a rate of approximately 1.75% per day for another week. The Morello fruits finished the period of very rapid growth four or five days before full ripeness but continued some enlargement for about nine days when growth practically ceased.

The above derivations were made during one season in New York and may or may not depict the growth rates for fruits of these varieties for the average year in various producing regions. They do, however, show the type of growth curves that prevail for early, mid-season and late ripening varieties of cherries.

E. MALFORMED FRUITS

Double cherry fruits are not uncommon but they seldom occur in sufficient numbers to increase the cost of handling appreciably. During 1932, however, the numbers of double sweet cherry fruits in certain producing areas of the western states affected the economy of production substantially. In one district of Idaho, 46% of the Bing, 43% of the Lambert, and 28% of the Napoleon fruits were double. Spurs produced a smaller percentage of double fruits than shoots.¹⁵

About one-half of the sweet cherries produced in the warmer sections of the Sacramento and San Joaquin valleys of California were malformed in 1932, while very little abnormality was noted that year in cooler regions. In most cases of abnormality double pistils developed in the normal position, resulting in double fruits at maturity. Pistils and petals were also found on the tips of filaments that normally support anthers. Such abnormalities seem to be associated with high temperatures during the period of fruit bud development.¹⁶

Asymmetric fruits develop when the seed is attached to the larger and better developed side of the carpel. In a simple fruit, like the cherry, the position of the embryo in relation to the carpel, and its point of attachment to that carpel, affects markedly the shape and development of a portion of the fruit.¹⁷

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SOME ENVIRONMENTAL FACTORS AFFECTING CHERRY PRODUCTION

Cherries formerly were grown rather extensively in areas that are no longer important commercially and the present districts of commercial production are quite well defined. Cherries cannot be produced economically in certain regions because of low yields, because of limited life of trees, or because it is impractical to combat diseases favored by climatic conditions. Furthermore, some regions have climatic and soil conditions favoring the production of the sweet varieties while others appear to be better adapted to red cherry production. Thus, the geographical distribution of the principal commercial producing areas for sweet and red cherry production is not a happenstance.

1. Light

One-year-old Montmorency trees grown in full sunlight at East Lansing, Michigan, made an average gain of 2.98 grams of dry matter per gram of leaves (dry weight basis). Trees shaded to provide approximately 50% of available sunlight produced 2.39 grams of dry matter per gram of leaves, and those grown under 30% available sunlight produced 2.13 grams of dry matter.¹

Reducing the light intensity in Montmorency trees in Wisconsin for a period of three weeks following full bloom by placing coverings of burlap, muslin, and cheesecloth over them, resulted in longer shoot growths and larger, thinner, lighter-colored, and more pliable leaves that contained less starch than those not subjected to shading. The shading also reduced the percentage of set of fruit.²

Similar methods of shading mature Montmorency trees during and for two weeks subsequent to the blossoming period in Michigan did not effect the development of the tree unless the light intensity was reduced almost 50% by the heavier burlap shading. Pollen germina-

tion, rate of pollen tube growth, time of fertilization, and rate of embryo growth were similar for shade and natural illumination.³

The above citations show that a substantial reduction in sunlight intensity is accompanied by a reduction in photosynthetic efficiency of the leaves and a reduction in percentage of set of fruit. They also offer a partial explanation for differentials in growth produced in the inner or shaded and the outer portions of trees. Whether natural light intensity is a factor of measurable importance in determining where cherries should be grown is questionable.

There is no indication that length of day, or duration of light, plays a part in determining areas of production for cherries. Both sweet and red varieties of cherries are grown commercially in North America over a range of 13 degrees latitude with seemingly equal success.

2. Water

Water is a normal constituent of all plant tissues as indicated by the following percentages in the several parts of the cherry plant: flesh of fruit, 89.98; stone, 46.81; stem, 68.76; leaves, 65.10; and new growth, 49.51.⁴ Water is a plant nutrient that is utilized in the manufacture of plant materials, particularly in the photosynthetic production of carbohydrates. It is also the medium through which nutrients and elaborated food materials are transported in the plant.

Water Requirement. Cherry orchards require less moisture than apple or pear trees. This is because cherry trees mature their crops in early summer and have relatively small water requirements during summer and autumn.⁵

The minimum water requirement for cherries is not known. They are raised successfully in some areas that have an annual precipitation of some 16 to 18 inches. However, two irrigations per season are seldom sufficient to supplement the rainfall in some areas of Colorado that grow red cherries commercially.⁶ Again, supplementary irrigation is sometimes made available for sweet cherries in localities of California that have a normal rainfall of 30 inches.

The seasonal distribution of rainfall is of nearly as much importance as total annual precipitation. The fruits ripen early in the season and most of the new shoot growth is made while the fruits are developing. Hence, the water requirement is relatively heavy during

spring and early summer. This happens to be the season during, or following, maximum soil moisture availability in most regions that grow cherries. A moderate supply of moisture must be available to cherry trees during the fall months to prepare them to withstand winter temperatures. This does not mean that there can be growth without rainfall or irrigation in late summer, but, rather, that the water requirements are substantially less than that of other kinds of fruit trees that are still developing their crops.

Soil Moisture. Cherry trees are susceptible to both deficiencies and excesses of soil moisture. Both young and mature trees may suffer from drought during any portion of the growing season. A severe drought may cause young trees to come into bearing early. The early bearing may be accompanied by a dwarfing of the trees that will cause them to remain small and unprofitable during the life of the orchards.^{7,8}

Cherry trees are more susceptible to defective soil drainage than either apple or pear trees. The trees frequently die when planted on poorly drained soils, while very favorable conditions for the growth and production of cherries usually prevail where the soil is well drained. Even a temporary rise in the water table may not be overcome by a subsequent favorable condition of soil drainage.⁵

The susceptibility of cherry trees to poor soil drainage applies to trees of all ages. Nursery trees develop poor root systems and tree mortality is high in soils that are poorly drained.⁹

High water tables at one season of the year may cause the trees to suffer from a lack of available soil moisture during another part of the season, even though precipitation may appear to be ample. In such cases the high water table results in root mortality below the level of the water table. The trees thus become shallow rooted and are unable to obtain water from soil below the level of root killing. Consequently, the moisture in the soil horizon explored by live roots is soon depleted and the trees suffer from drought.

Transpiration. Evidence accumulated during recent years indicates that the cherry may be more responsive to water deficits resulting from high transpiration rates, while the trees are maturing their fruits, than some other tree fruits. When red cherry trees are sprayed with Bordeaux mixture or materials containing copper, they produce fruits that were smaller than those grown on trees that are not sprayed or those that are sprayed with materials that do not contain copper. The smaller size of the fruits results from increased transpiration

caused by the spray material.^{10 13} These investigations indicated that a reduction in transpiration rates, even in a humid climate, might make possible larger fruits and consequently larger yields. Thus, the weight of fruits was increased nearly 10% by applying sprays of an oil-wax emulsion to reduce transpiration in a year when available soil moisture was about normal for the region.¹⁴ (See Chapter VII.)

If the cherry fruits are undergoing development during weather characterized by high temperatures and low atmospheric humidity, high transpiration rates may cause very substantial size reduction in fruits. The volumes of 12 varieties of red and sweet cherries in Illinois were measured at regular intervals between shuck fall and ripening in a year when the month of June was characterized by clear and hot weather with no precipitation during the first 25 days. The fruits of six of the 12 varieties showed a decrease in volume and shriveling as they approached maturity and the other six varieties did not shrivel though they failed to attain normal size. The shriveling and failure to develop normal fruit size was not due to a soil moisture deficit. The high transpiration rates in June from extensive leaf areas caused water to be drawn from the fruits during the day and six of the varieties were unable to recover during the night.¹⁵

Cherries are probably more sensitive to such high transpiration rates, and the resulting daily water deficits, than most deciduous fruits. The cherry fruits are small and contain a high percentage of water. Thus, a high percentage of water can be removed from them during a hot day, with low atmospheric humidity, causing a water deficit in the leaves and movement of water from the fruits to the leaves.

Cracking or Splitting of Fruits. Cracking of sweet cherry fruits was thought to be associated with excessive absorption of water through the roots of the trees until evidence was produced to show that it is due to an osmotic absorption of water through the skin of the fruit. The sweet cherry may increase as much as ten percent in volume during the ripening period because of osmotic intake of water through the epidermis of the fruit when rains occur. This rapid swelling of the underlying tissues causes the skin to stretch and finally split.¹⁶ The absorption of water through the skin of the fruit during and following rains is affected directly by (1) the osmotic concentration of the fruit juice, (2) the turgor of the fruit, (3) the temperature of the water, and (4) the permeability of the epidermal layers of the fruit.¹⁷ Cherries which are likely to crack also have a higher proportion of

pectic substances than those which do not crack.^{17a}

Three distinct types of cracking are recognized: (1) circles or semi-circles around the stem end; (2) very fine concentric rings together with deeper, crescent-shaped cracks at the apical end, and (3) long irregular slits on the sides of the fruit. The cracks at the apical end are the most common and are the first to occur, but they are the least noticeable.¹⁷

Cracking occurs only when the fruit becomes wet with the occurrence of rain or fogs or upon immersion in water. No cracking occurred when the branches supporting fruits were protected from rain. When harvested fruits were immersed in water, the rate of absorption of water was proportional to the osmotic concentration of the juice of the fruit. When the fruits were immersed in sugar solutions, the volume increase and the amount of cracking varied inversely with the concentration of the sugar solution.¹⁷

Cracking is likely to be more severe just before full maturity, rather than later when osmotic concentrations are higher. This may be because the fruits have a lower degree of turgidity at full maturity than they have just prior to this stage of development,¹⁷ or it may be so because the tendency to crack increases to a maximum when the sugar content of the fruit reaches approximately 20%.¹⁸ The tendency to crack increases with an increase in the temperature of the water.¹⁷ At approximately 20°C., an increase or decrease of one degree varied a cracking index plus or minus 20 points.

Table 7 shows that each successive rain increased the amount of cracking of the Bing variety. These cherries were picked in the early forenoon on successive days during and following four days that had a total of 1.4 inches of precipitation distributed over a total of 20 hours.¹⁹

The ascending order of susceptibility of some varieties in the Pacific Northwest is Montmorency, Lambert, Napoleon, and Bing. The skin of Montmorency has a low rate of permeability while that of Bing is the most permeable of the four varieties.¹⁸ There was no loss with Black Tartarian, 6% loss with Schmidt, and 23.5% loss with Windsor in Ontario during a season having weather relatively favorable for cracking. In general, cracking is not a serious problem with the red varieties.²⁰

Spraying the trees with such materials as Bordeaux mixture or hydrated lime before harvest has reduced the amount of cracking.^{21,22} Since hydrated lime sprays were as effective as Bordeaux it was con-

TABLE 7. CRACKING OF BING CHERRIES AT HARVEST IN RELATION TO CUMULATIVE EFFECTS OF SUCCESSIVE RAINS¹⁹

Picked		Rainfall			Cracked fruit, mean percent		
Date and time (A.M.)	Hours after 1st rain	Amount, in.	Duration, hr.	Time	Slight	Severe	Total
June 16, 10:30	0.5	1.08	16.5	4-10 A.M., 2:30 P.M.-12 M.	45.7	3.5	49.2 ± 1.41
June 17, 8:30	22	0.10	1.0	12 M.-1 A.M.	29.5	41.2	70.7 ± 1.69
June 18, 9:00	48	0.12	1.5	4-5 A.M., 2-2:30 P.M.	35.0	39.6	74.7 ± 0.74
June 19, 8:30	72	0.10	1.0	5-6 P.M.	37.7	40.3	78.0 ± 0.46
June 20	---	None	---	---	---	---	---
June 21, 8:30	120	None	---	---	41.9	35.1	76.9 ± 0.53

cluded that calcium was the effective agent. Inasmuch as both the Bordeaux and hydrated lime sprays leave objectionable residues on the fruits, such sprays should be applied early in the season so that weathering and increase in size of fruit will reduce the concentration of residue on the surfaces of the fruit.²¹ Other promising sprays for the reduction of the tendency of fruits to crack are aluminum and the sodium salt of α -naphthalene acetic acid.¹⁸

An application of one pound of borax to a soil that was low in available boron reduced the amount of cracking of three varieties of sweet cherries 25 to 50% during the current season of application in Oregon. No cracking was observed in cherries that had been sprayed or dusted with 0.01 to 0.25% anhydrous copper sulfate and were then submerged in water for four days. Since the concentrations used were too low to have an osmotic effect, the investigators believe that the copper sulfate has a tendency to toughen the skin and fruit and that it affects the cells so that less water is absorbed and held during and following rains.²³ It is possible that some of the results just reported may have been influenced by altering the pH of the water that comes in contact with the fruit.²⁴

Some growers of sweet cherries shake the water from trees after rains to reduce cracking. A practice recently adopted by a number of producers is to drive along tree rows, immediately following rains, with a truck on which is mounted a gasoline engine that drives airplane propellor blades rapidly enough to blow water off the fruits. The helicopter also has been used commercially in California to blow water off the fruits following rains.

3. Temperature

Temperature plays a more important part in determining where fruits may be grown successfully than any other one factor. The maximum latitudes or altitudes for successful culture are often determined by minimum winter temperatures and the southern limits of commercial production in the northern hemisphere are fixed by maximum and mean summer temperatures. Within the limits of latitude determined by winter and summer temperatures, areas of production also may be determined by temperatures that prevail during spring, especially during the pre-blossoming and blossoming periods.

A. WINTER TEMPERATURE

While the red cherry may withstand temperatures as low as $-30^{\circ}\text{F}.$,²⁵ there is at least one instance of record when trees died during a winter when temperatures did not go below zero.²⁶ In the latter case, there was not sufficient hardening of tissues during the fall months. Generalizations must be accepted with some reservations.

The common varieties of red cherries are not as resistant to winter cold as the Northern Spy apple²⁷ or the American and Japanese varieties of plums²⁸ but are more hardy than the Baldwin apple²⁹ or the European plums and the pears.²⁸ Even though the red cherry is regarded as one of the hardiest tree fruits, winter injury is a most important factor in determining the longevity of trees.³⁰

The sweet cherry is more tender to winter cold than the red cherry, but it is hardier than the apricot or the peach. Thus, the northern limit of commercial production in the northern hemisphere is intermediate between that for the red cherry and the peach. It is generally assumed that the varieties usually grown will withstand minimum temperatures of -15 to $-20^{\circ}\text{F}.$ without injury.^{25,30} Such assumption presupposes that the trees have been properly prepared for winter by an adequate moisture supply during the preceding summer and proper hardening in the fall.

The Duke cherries are less hardy than red cherries and hardier than the sweet varieties.

Other than killing caused by extremely low temperatures, most of the types of winter injury occurring in the above-ground woody tissues of trees may be classified as follows: (*a*) those due to immaturity of wood because of late growth prior to the onset of low temperatures, resulting in bark splitting on the trunk and larger branches and crown and crotch injuries; (*b*) those due to immaturity of tissues attributable to premature defoliation, including blackheart and die-back of twigs and branches; and (*c*) those due to great diurnal temperature differences in the tissues resulting in sunscald.

Crown and Crotch Injury. Sweet cherry trees are much more susceptible to crown and crotch injuries than are red cherry trees. Such injuries are more likely to occur following a prolonged period of growth and delayed maturity of wood. They may also occur when temperatures in October or early November drop to levels approaching zero (Figure 16). In such cases, the tissues of trees, especially young and vigorous ones, may have not had time to harden sufficiently to resist injury.³¹⁻³³

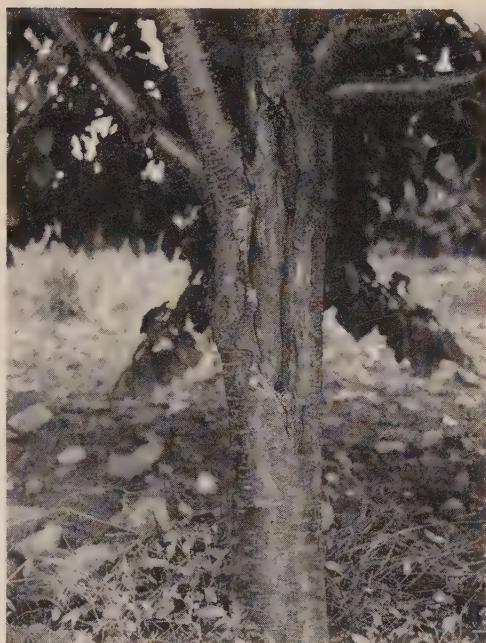


Figure 16. A sweet cherry tree showing winter injury to crotch and trunk. The injury occurred in New York after the late growing season that preceded a freeze in early December 1942. (Courtesy of M. B. Hoffman, Cornell University.)

Bark Splitting. Bark splitting, characterized by vertical splits or cracks on the trunks, was the most serious type of injury noted on young sweet cherries in Washington after the late autumn freeze of 1935.³³ These cracks may be narrow and may or may not extend into the sapwood. The bark may roll back along the edges of the crack, exposing the underlying tissues. Sometimes the bark separates from the sapwood on either side of the crack (Figure 17). It is favored by failure of the wood of tree trunks to mature properly before low temperatures occur in fall or early winter.

Sunscald. Sunscald occurs on the trunks and sometimes on the larger branches. It is of more common occurrence when the temperature of the tree trunk is greatly elevated by both the direct rays of the sun and the reflection of the sun's rays from snow. The injury is likely to be more severe on the southwest side of the trunk because the tem-



Figure 17. Trunk of Montmorency cherry tree showing a type of winter injury often caused by rapid changes in temperature. The injury occurred several years before the photograph was made.³⁴

perature differentials from day to night are greatest on that side. It may be caused any time during the winter, but occurs more frequently in late winter. Severe sunscalding causes the death of bark and sapwood tissues and thus has the same effect as a partial girdling of the tree trunk. Large areas heal slowly and offer an opportunity for destructive fungi to aid in the killing of the tree. The most effective control is to develop low-headed trees that provide some shading of the trunk during mid-afternoon.³⁵

Blackheart. Blackheart contributes to the death of more cherry trees, both sweet and red varieties, than all other types of injuries combined.²⁹ Death may occur after winters of no great severity³⁵ and again it may be traced back to injury that occurred several years previous.³⁶ A more or less lingering death is common where blackheart injury occurs.

Blackheart is characterized in the early stages of development

by light brownish heartwood which becomes dark brown or even blackish in time. It may occur in any kind of wood such as the trunk, branches, fruit spurs, or shoots. The injured sapwood loses its conductive properties and the food material stored in it is no longer available to the plant. The tree, thus becomes progressively weaker because of deprivation of water and nutrients to the foliage and because some stored food materials are no longer available. Fungi gain entrance to the killed tissues, causing them to rot and weaken. These fungi are also capable of living in live sapwood tissue and therefore grow into the new wood soon after it is formed.⁷ Thus, a black-hearted branch may appear to have only one annual ring of live sapwood. Trees may overcome a blackhearted condition but they are more likely to live one to several years, becoming weaker each succeeding year until death finally comes.

Dieback. Dieback of branches in the top of the tree may be associated with the same conditions that cause blackheart (premature defoliation).^{29,36} Branches or terminal shoots of a tree may also be winter killed because of low temperature associated with lack of maturity due to late growth in the fall³⁶ or summer defoliation.³⁷

Bud Injury. Fruit buds of the red cherry are more hardy in winter than those of the peach³⁵ but usually are less hardy than buds of the apple,³⁸ and the buds of sweet cherry are a little hardier than those of the peach.²⁸ The degree of hardiness is greater when the buds have not attained advanced stages of development in early winter.²⁷

A slow rate of temperature fall resulted in less killing of buds of Montmorency and Early Richmond than a rapid temperature drop to the same level.³⁹ Temperatures of -22 to -37°F . in February, 1934, killed only 5 to 20% of the buds of Montmorency trees on some locations in Michigan, while on some other locations serious reduction in numbers of live buds resulted at higher temperatures.⁴⁰ Much injury to buds occurred in many eastern and midwestern areas during the severe winters of 1917-1918 and 1935-1936.^{28,41} All flower buds of sweet cherries were killed at -15°F . during a severe winter in Ohio.²⁸ These citations indicate clearly that the amount of bud injury at a given low temperature cannot be predicted.

A delayed winter killing of flower buds is believed responsible for the killing of five to ten times as many Montmorency buds in Michigan as are killed by much lower temperatures when the buds are dormant. This injury occurs at a stage when advancement from dormancy is so slight that it is often regarded as a form of winter injury.⁴⁰

Root Injury. Mortality among cherry trees resulting from killing of roots by low temperatures in winter is more likely to be a hazard in some of the dry, sandy soils when the snow cover is light than in the heavy soils that are well supplied with moisture. Cold penetrates much less in the latter because heat is released owing to the great amount of water present.²⁵ Trees growing in soils that are poorly drained during portions of the year may be shallow rooted and surface killing of roots by low temperatures in winter may contribute to their death.

Mortality of trees due to root killing was common in New York in 1928. Some trees died without leaving-out, some died at the time of blossoming, some lived until transpiration during dry and hot summer weather exceeds the water supply of the limited root system, and others died a lingering death during periods extending over one to three years.³⁶

Winter Rest Period. In districts having moderately warm winters, the temperatures may not be low enough to break the rest period. This is a problem in some areas of production in California. Lambert, Napoleon, and Bing often show a marked delay and irregularity in blossoming following relatively warm winters, while such varieties as Black Tartarian, Burbank, Chapman, and Republican are affected very little. Lambert, grown in coastal valleys adjacent to Monterey Bay, has been observed to be in full bloom at the time that the Black Tartarian was ripe following unusually warm winters. Under the same conditions, Napoleon displayed all variations of development from blossoms to ripe fruit. This behavior of Lambert accounts, at least in part, for the fact that this variety is less desirable in California than in the Pacific Northwest, where the winters are colder.⁴²

B. SPRING TEMPERATURE

The killing of flower buds by spring frosts is the greatest hazard in cherry growing in most areas.^{8,43} Sixteen percent of 422 Montmorency cherry orchards in Michigan produced less than 40% of a full crop over a period of nine years and only 11% of the orchards averaged 90% of a full crop, for the same years. Drought, wind, and winter freezes accounted for some of this crop reduction, but damaging temperatures occurring during the late preblossoming and blossoming periods were especially important factors. Loss from frost occurred less frequently than once in five years on the better sites.⁸

The most critical period in spring for the Montmorency variety occurs three to four weeks prior to blossoming when the individual flower buds have attained one-fourth to one-half the size they reach before opening into flowers. They are much more sensitive to frost damage at that time than when fully expanded and are more susceptible to damage than are apple, pear, and peach buds at that time. A temperature of 28°F. at this stage is likely to reduce the crop substantially.^{8,40}

A survey in Utah indicates that some damage to sweet cherry flowers in full bloom may result at 29°F. and that about one-half of the flowers may be killed when the temperature drops to 25°F. Red cherry flowers are somewhat hardier; a temperature of 26°F. usually kills about one-fifth of the open flowers. Flower buds showing color withstand temperatures two to four degrees F. lower than do open flowers of both species.⁴⁴

The best protection against crop losses due to killing of flower buds or flowers by spring frosts is to provide a suitable site for the orchard. Even a slight difference in relative elevation of the site may mean the difference between a full crop and no crop in some years.

Adverse weather during the blossoming period may reduce the set of fruit substantially even though temperature conditions permit normal development of the pistils. Either rainy weather or moderately low day temperatures may prevent the bee activity that is essential for pollen distribution, and high atmospheric humidity may prevent the shedding of pollen even though other conditions are favorable to bee flight.³

A liberal flow of nectar is necessary to attract bees to flowers and only a limited flow of nectar takes place during periods of low atmospheric humidity or when the temperature range is below 65°F. or above 75°F. Periods of abnormally high temperatures also may shorten the blossoming period to such an extent that otherwise normal bee populations do not have time to do an adequate job of pollen distribution.⁴⁵

C. SUMMER TEMPERATURE

The main centers of production of the red cherry are where the mean temperatures for June, July, and August are about 60°F.²⁵ and the sweet cherry ripens better in the very cool summers of the San Francisco Bay Region than other species of tree fruits.³⁸

Regions that are hot and humid favor the development of the fungus causing brown rot of ripening fruits. However, the sweet cherry is a little more tolerant of high summer temperatures than the apple but is less tolerant to summer heat than the peach, the apricot, or the European plum in California.²⁷

Hot periods in mid-summer are responsible for the development of abnormal flowers and double pistils. Twenty to thirty percent double fruits may occur on the Bing and Napoleon varieties during years following hot periods in July and August in the Sacramento Valley, while double fruits are rare in the cooler coastal valleys of California.⁴²

Temperature also affects the maturing of the fruit. Night temperatures of 60 to 65°F. enabled Montmorency fruits to complete the final swell in 16 days, whereas nearly twice as long was required with night temperatures of 91°F. Cherries produced under the former conditions had 13.4% sugar compared to 9.7% for the latter.⁴⁶

4. Soil

↓ Good soil drainage is of paramount importance for cherries. Soils that are water-logged, even in winter, may make sweet cherry trees susceptible to all the ills attacking them,⁴⁸ and the presence of

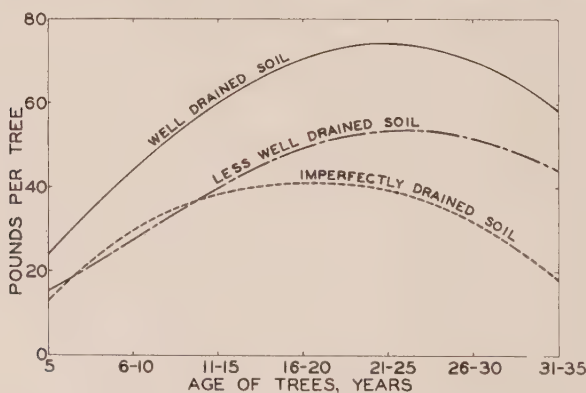


Figure 18. The relationship between soil drainage and yields of red cherry trees in Monroe County, New York. Yields of trees on well-drained soils increase rapidly as the trees approach maturity, and they remain at substantially higher levels than those for trees located on soils that are less well drained.⁴⁷

underlying hardpans that favor a water-logged condition in the soil is undesirable.⁴⁹ Drainage conditions should be such as will encourage extensive root development to a depth of four to six feet, and the continued maintenance of such roots. (If the soil is well-drained, the other soil characteristics are of secondary importance.)

Cherries are tolerant of a wide variety of soil types if drainage is adequate. The more favorable soils in Michigan are intermediate in texture; they contain sufficient sand and gravel in the sub-soil to permit root penetration and, at the same time, contain enough silt and clay to

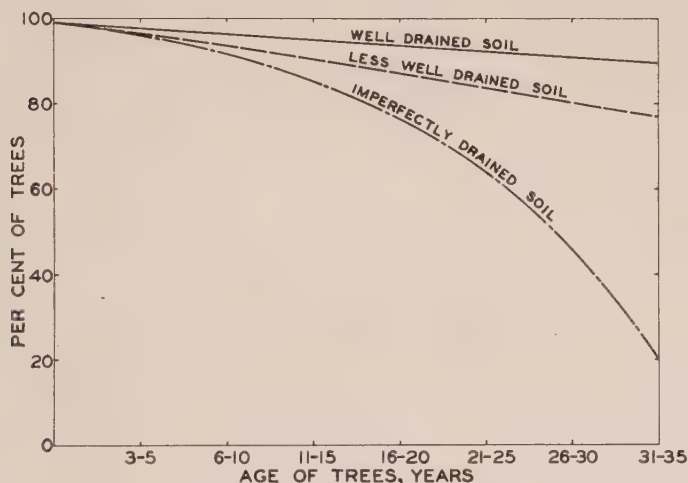


Figure 19. Percentages of original red cherry trees remaining in orchards at given ages on different soils in Monroe County, New York. Note the heavy mortality in older orchards on imperfectly drained soils.⁴⁷

retain moisture during droughty periods.⁴⁹ Sandy soils are likely to be droughty because of their low water-holding capacity.⁵⁰ Heavy clays and heavy loams are not objectionable for red cherries if they have good drainage, such as might be provided by a sub-soil of gritty clay of rather open structure. Shallow shaley soils are not suitable since they limit root production.⁶ The alluvial sedimentary soils along the rivers in California are ideal for the sweet cherry and the mellow soils of the foothills are also suitable. Clay and adobe soils are very unsatisfactory.⁴²

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SOME MANAGEMENT FACTORS AFFECTING CHERRY PRODUCTION

1. Rootstocks

The cherry reproduces truer to type than most other tree fruits, but exact varietal characteristics cannot be reproduced except by asexual propagation. Since cuttage and layerage are impractical with the cherry, the nurseryman resorts to budding or occasionally to grafting.

Several steps are employed in the development of a cherry tree prior to the time that it is ready to plant in the American orchard. Seeds from certain types of cherries are planted in a nursery and the resulting seedlings are grown for one season when they are dug and "lined-out" in rows in the nursery during the spring of the second season. They are then grown until late mid-summer when buds from current season wood of the desired varieties are budded into these seedlings just above the ground level. These individual buds then unite with the seedling trees and the latter are cut back early in the following spring just above the inserted buds. The buds are allowed to grow one or two seasons in the nursery when the resulting one- or two-year-old trees on a three- or four-year-old roots are offered for sale.

The cherry tree thus consists of two portions that have been joined together by budding: that grown from seed becomes the root system and is called the *stock*, the *rootstock*, or the *understock* and that developing from the inserted bud of a designated variety becomes the above-ground portion of the tree, known as the *cion*.

The procedures in some countries may differ from the above. In England, wild trees are dug in the woods or hedgerows and then grown in the orchard or in a nursery for one year, at which time the cion is grafted onto the stem at a height of six feet in the case of sweet cherries or three feet in the case of red cherries.¹

Mazzard vs. Mahaleb Rootstocks. The principal rootstocks for cherry trees are Mazzard and Mahaleb. Mazzard is the term applied to the wild sweet cherry that has been used as a stock since the earliest cultivation of cherries. It was the only stock used in America from the time of its introduction about 1730 until the middle of the last century.

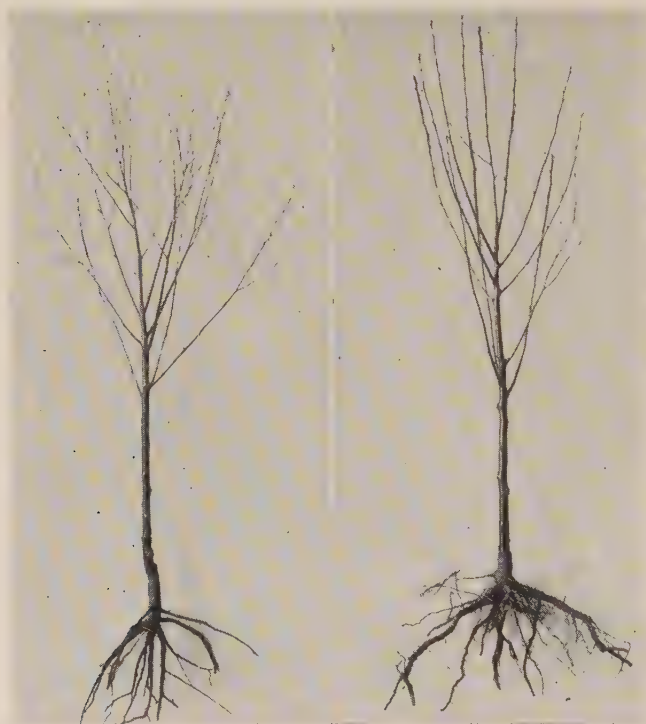


Figure 20. Montmorency nursery-grown trees on Mahaleb roots (left) and Mazzard roots (right). Note differences in the growth habit of the two kinds of root systems, and note that the rootstocks have influenced the character of the growths above the bud unions. The Mazzard rootstock has overgrown the Montmorency at the bud union.⁵

Mahaleb became the more popular stock for sweet and red cherries by 1880² and a survey made in 1926–27 showed that practically all nurseries in the North Atlantic States grew cherries on Mahaleb.³

The question as to which of the two stocks is the more desirable has been controversial for a number of years. Some authorities claim

that Mahaleb is preferable where winter injury is a factor.^{4,9} However, there are isolated wild Mazzard trees that have withstood temperatures of -20 to -30°F .¹⁰ Mahaleb has greater resistance to alkaline soils and withstands dessication better than Mazzard.^{6,9} Mazzard seems to be more tolerant of poorly aerated and poorly drained soils^{9,11,12} and most investigators claim that trees on Mazzard roots grow larger size and live longer, provided winter injury is not a factor.^{5,11-14} There are cases, however, where dwarfing of sweet cherry trees by means of Mahaleb stocks may be desirable.^{9,15}

Nurserymen prefer to grow cherry trees on Mahaleb stocks for the following reasons: Mahaleb is less susceptible to defoliation in the nursery by the leaf spot fungus than is Mazzard; the percentage of bud "take" is higher on Mahaleb, and trees grown in the nursery on Mahaleb roots have better appearance at sales time. Thus, nurserymen produce salable cherry trees on Mahaleb at lower cost.¹⁶

It may be that the stock problem is not a question of Mazzard vs. Mahaleb, but performance of one group of seedlings from a known parent or strain against another. Thus, the time may come when seed propagated, or even asexually propagated, strains may be in general usage for specific varieties.¹⁰ A number of clonal stocks of the Mazzard type have been tested in England and one designated as East Malling F 12/1 has given superior performance.¹⁷

Day⁹ suggests several methods that may be used to distinguish between Mazzard and Mahaleb roots.

Other Stocks. A clonal rootstock known as Stockton Morello is used extensively for sweet cherries in the Stockton district of California. It is more resistant to heavy, wet, poorly aerated soils than is Mazzard and it causes trees to be more dwarfing and more spreading.^{9,15} Such species as *Prunus pennsylvanica*, *P. virginiana* and *P. serotina* have been tried as stocks for cherries, usually with disappointing results. *P. sargentii* likewise results in weak, short-lived trees.¹⁸ *P. besseyi* is used occasionally in some of the cold and dry regions for the red cherry.

2. Establishing the Orchard

Planting Distance. Except for contour plantings, cherry trees are usually planted in squares. The distance between red cherry trees in orchard plantings ranges from 15 to 30 feet, while that for sweet

cherry trees ranges from 24 to 40 feet.^{19,20} Average planting distances are about 20 to 22 feet for red cherries and 28 to 35 feet for sweet cherries. There is a high correlation between close planting and high yields¹⁹ but even the average planting distances do not provide adequate space between rows of mature trees to facilitate the proper operation of large power sprayers. Planting the trees in rectangles 17 to 18 by 24 feet for red cherry trees and 25 to 28 by 32 to 35 feet for sweet cherry trees seems to solve the spraying problem without allowing undue space to each tree.

Where cherry trees are planted on contour lines to forestall erosion, 400 to 500 square feet should be allowed for each red cherry tree and 750 to 1,000 square feet for each sweet cherry tree.

Age of Nursery Stock. Trees that are one or two years from time of budding in the nursery may be planted. It is customary, however, to plant one-year-old sweet cherry trees and two-year-old trees of the red and Duke varieties because trees of the latter varieties are usually small at one year from budding.

Spring vs. Fall Planting. Planting losses are probably greater with the sweet cherry than with any other kind of fruit tree and they may be great with the red cherry. This is partly because the buds of the sweet cherry are large and are rather easily rubbed off in handling and partly because the buds expand and open early in the spring, while the root system is slow in becoming established. Thus, water losses from the early developed top cannot be met by the slowly developing root system unless the soil moisture supply is ample. It is therefore essential that the trees be planted before the buds have started to swell if the planting is done in the spring.

Fall planting of trees is preferred over spring planting in some regions. Roots of fall planted trees grow and develop through the winter months in Western Oregon, but severe winter conditions in the eastern part of that state make spring planting advisable.¹⁹ If fall planting is practiced, it must be done early enough to result in some rooting before winter and at a time when the soil is not wet enough to limit oxygen supply to the roots. However, growers should not resort to it in New York unless they can afford the losses that may follow due to adverse weather.⁵ Fall planting of sweet cherry trees is recommended for eastern Ontario because they begin growth earlier in the season than spring-planted trees and are better able to withstand drying conditions during the spring months.²¹ About 25% of recent

plantings of red cherry trees in Michigan have been planted in the fall. In general, it would seem that fall planting is desirable in regions where winter temperatures are not too severe.

Planting the Trees. It is important to have a well-aerated soil when starting young cherry trees in the orchard. Mixing peat with the soil placed about the tree roots at planting time will increase aeration. Tukey⁵ found a wet soil provided only 8.1% air while a wet peat-soil mixture had 39.1% of its volume occupied by air. The percentage of the space occupied by water was essentially the same in each case. The trees planted in the peat-soil mixture showed 109% gain in top growth over those planted in soil.

Waxing trees with a mixture of petroleum jelly and paraffin at planting time has not proved advisable. The petroleum jelly seemed to injure the bark where it penetrated and it caused sprouting at the base of the tree.²¹

The young tree at planting time usually contains enough stored food materials to provide for initial growth. Fertilization at planting time, therefore, is unnecessary, and may even be disastrous since the fertilizer may injure the roots or it may cause excessive top development followed by death in a dry season.⁵ However, trees planted in soils containing less than 50 pounds per acre of potassium made 14% more terminal growth and 80% more trunk diameter when fertilized with one gallon of a solution containing two pounds of potassium chloride per 100 gallons, whereas the use of dry fertilizers at planting time frequently resulted in death of the trees.²²

Tree Training. The branches on both sweet and red cherry trees should be headed back immediately after the trees are planted to establish a balance between the reduced root system and the tree top. The red cherry tree may only "feather out" if the branches are not cut back. If the branches are too low, the tree that is one year from budding should be pruned to a whip at planting time. Otherwise, each lateral may be cut back to leave eight to ten buds.²³ The leader should be two to three inches longer than the lateral branches.²⁴

There should be three or four lateral branches spaced about 8 inches apart along the main axis of a sweet cherry.¹⁹ The growth response of two-year-old sweet cherry trees cut back to two or three buds at planting time was not significantly different from that of trees with one-third of the lengths removed, but both lots of pruned trees gave better growth response and better tree survival than unpruned

ones. Removal of the terminal buds retards growth and pruning the top reduces the transpiring surfaces to the point where the slowly developing root system can meet the water requirements.²¹

Cherry trees are generally trained with a central leader or modified leader from which there should be five or six main wide-angled scaffold branches distributed along and around some three feet of trunk with lowest one arising about 20 inches from the ground level on the southwest side of the tree.

The main purpose of tree training is to establish the leader and its lateral or scaffold branches. Very little other pruning is essential or even advisable. Heavy pruning delays the time of fruiting and also has a tendency to dwarf the tree. Only light corrective pruning is necessary. Young sweet cherry trees may need to be cut back moderately to prevent the development of pole-like branches.

* *Cultural Management for Young Trees.* Cherry trees usually begin to produce fruit three to five years after planting in the orchard and they may be expected to reach full-bearing capacity, for their size, when the trees have attained an age of about ten years. During the first four or five years after planting, the soil management should be designed to obtain a well-developed root system and vigorous shoots that support an extensive leaf area to manufacture materials for growth. The trees should make this vigorous growth during spring and early summer. During late summer and fall the trees should mature the wood so that there will be less likelihood of winter injury.

These goals are achieved by providing cultural practices that will make available to the trees an adequate supply of soil moisture and nutrients during the spring and early summer but will limit the supply of them during the late summer and fall. This means that the orchard, or at least the land along the tree rows, should be cultivated during the early portion of the growing season and that annual cover crops that will compete with the trees for soil moisture should be sown in early summer in most producing trees. It may also be advisable to apply a nitrogenous fertilizer in the spring to promote the desired amount of growth.

In cases where cultivation is limited to a strip on either side of the rows of trees, the areas between the cultivated strips may be planted to perennial cover crops to retard erosion and to improve the physical condition of the soil.

3. Pruning Mature Trees

Fruiting Habit. Sweet cherry trees produce most of their fruits on spurs, while red cherry trees produce fruits on spurs and from lateral or axillary buds on shoots. Spurs are short growths that usually grow less than an inch in any one year. They arise from lateral leaf buds, usually on shoots that are one year old. Cherry spurs always have a terminal leaf bud and several flower buds that are borne laterally, in more or less of a cluster on the portion of the spur that grew during the previous season. Since the terminal bud is a leaf bud, the spur elongates in practically a straight line for several successive years.

Sweet cherry spurs may remain productive for 10 to 12 years and this persistent spur system makes it necessary to prune less wood from sweet cherry trees than from other deciduous fruit trees.²⁵ Red cherry spurs, however, are usually short-lived. Those on two-year wood are the most vigorous and productive and those on three-year wood are normally quite productive, but only a few good ones are found on four- and five-year old wood.²⁶

The fruiting habit of the red cherry varies with varieties and with the age and vigor of the tree. The more vigorous shoots normally produce mostly leaf buds that develop into lateral shoots and short spurs during the following growing season. Leaf buds on very strong growing shoots may produce laterals at the expense of spurs. This condition may prevail in young trees. Shoots that are six to ten inches in length are generally most satisfactory because the leaf buds borne on them will usually develop one or two lateral branches and several fruit spurs. Shorter shoot growths are likely to have several flower buds and few leaf buds.^{26,27}

About one-third of the shoots on high producing Montmorency trees in New York were six to ten inches in length and about one-third of them were 11 to 15 inches long. These growths usually produced both spurs and strong laterals. On the other hand, moderately producing trees that formed few spurs or laterals had shoots that were mostly less than five inches long.²⁷

Increased yields of red cherries are brought about only through an increase in the number of fruit buds. This can be accomplished principally through the production of new side shoots from lateral leaf buds in the case of the English Morello and principally through the formation of new fruit spurs in the case of the Montmorency

(Table 8). In both varieties, shoots eight to ten inches in length must be grown to increase the bearing surface, and longer growths will result in more rapid increase in bearing surface. A shoot length of four to eight inches, however, is adequate to maintain yields of trees that have attained full size and productivity.²⁶

English Morello trees produce greater proportions of their fruits on shoots than do trees of the Montmorency variety. Most old and weak trees of this variety fruit principally from lateral buds borne on shoots. Frequently, all of the buds on shoots less than six inches in length are flower buds. Since there are no leaf buds, lateral shoots or

TABLE 8. FRUIT BUD, FRUIT SPUR, AND LATERAL SHOOT PRODUCTION OF MONTMORENCY AND ENGLISH MORELLO SHOOTS OF DIFFERENT LENGTHS²⁶

Length, in.	Montmorency			English Morello		
	Ave. No. lateral fruit buds	Ave. No. fruit spurs formed subsequently	Ave. No. lateral shoots formed subsequently	Ave. No. lateral fruit buds	Ave. No. fruit spurs formed subsequently	Ave. No. lateral shoots formed subsequently
0- 1	5.7	0.1	0.0	4.0	0.0	0.0
1- 2	6.5	0.1	0.1	6.0	0.0	0.1
2- 3	7.9	0.3	0.1	6.9	0.1	0.1
3- 4	8.9	0.3	0.1	8.0	0.1	0.0
4- 5	9.1	0.4	0.2	9.0	0.1	0.2
5- 6	9.4	0.5	0.3	9.9	0.2	0.3
6- 7	9.0	1.3	0.7	10.6	0.2	0.6
7- 8	8.6	1.6	1.1	10.6	0.1	1.0
8- 9	7.7	2.6	1.4	11.0	0.5	1.9
9-10	7.5	3.0	2.0	10.4	0.8	2.6
10-12	7.3	3.8	1.9	8.7	1.1	4.3
12-28	4.9	4.9	3.7	5.5	2.6	6.7

spurs cannot be formed. This results in a completely barren area along the shoot after it has fruited. These shoots may elongate a few inches each year and after a few years long twigs result that are barren except for a few clusters of fruit, and their attending leaves, on the second season wood and leaves and flower buds on the current season growth. Shoots can be made to produce some leaf buds that will develop into spurs and lateral shoots by providing cultural practices and pruning that will force the growth of longer shoots.

Roberts²⁸ favors the maintenance of a good spur system for the three principal red varieties in Wisconsin because spur-borne flower

buds give better winter survival and better setting of those that survive the winter than shoot-borne buds. On the other hand, Gardner²⁶ contends that the Michigan grower need give little or no attention to the question of spur vs. shoot fruiting. His records indicate that Montmorency trees normally produce from one-third to 45% of their fruits on shoots. When marked increases in yield were obtained, the yield increases were associated with both increased shoot growth and new spur formation.

A number of barren strains of the Montmorency cherry have been noted in which barrenness is due to the failure of the trees to form flower buds in positions where such buds are normally differentiated or because leaf buds occur in positions where flower buds are ordinarily formed.²⁹

Pruning the Sweet Cherry. Properly trained sweet cherry trees require very little pruning. They have a rather open growth habit and the foliage is well exposed. In fact, the trees often have a tendency to develop long-pole-like branches. Thus, there is seldom need for the thinning-out type of pruning.

Tufts²⁵ suggests an annual heading back to lateral branches at the base of one-year-old shoots, designed to renew about 10% of the bearing wood each year. Heading back onto wood that is two or three years old may prevent the formation of new shoots on the headed branches. Removal of dead wood immediately after harvest is also recommended in California.¹⁵

Pruning the Red Cherry. Most growers prune mature red cherry trees very little and the experimental evidence seems to justify this practice or lack of practice. Table 9 shows that a light pruning of

TABLE 9. EFFECT OF PRUNING ON FRUITING RECORDS OF 16-YEAR-OLD MONTMORENCY TREES, AVERAGES PER TREE²⁶

Treatment	Shoot-borne fruits		Spur-borne fruits		Total fruits	
	Number	Yield, lb.	Number	Yield, lb.	Number	Yield, lb.
Pruned	6,152	60.7	8,813	84.0	14,967	144.7
Unpruned	5,906	55.5	11,815	108.2	17,721	163.7

16-year-old Montmorency trees, that consisted principally of the removal of some of the smaller limbs in portions of the trees that had become thick and brushy, reduced yields nearly 12%, and reduced the

percentage of spur-borne fruits from 67 to 59%. In another Montmorency orchard that had not been pruned for six to eight years, the average annual yields per tree for the four-year period were 103 and 91 pounds respectively, for the unpruned and pruned trees.²⁶



Figure 21. A 12-year-old Montmorency tree that has received no pruning for five years and very little before that. It is too bushy for uniform ripening of high-quality cherries, for thorough spraying, and for easy harvesting of the fruit. Some thinning of weak limbs in the center, however, is all that is needed. Note the strong, well-spaced branches.³⁰

Pruning reduced yields on five- and six-year-old trees in Colorado proportional to the severity of the pruning treatment. Yield reduction was due to the removal of fruit buds in pruning. There was a tendency, however, for size of fruit to increase with severity of pruning.⁶

When the tops of red cherry trees are cut back severely to outside branches to renew them, the growth of the trees was checked during the first season and the yields were decreased for three years, compared with no treatment. However, when the pruned trees were also fertilized, they produced many new shoots by the end of the third year and appeared more vigorous than untreated trees.²⁷ The author obtained very similar responses in Michigan from trees which were

similarly headed back following winter injury to roots of Montmorency trees.

The Wisconsin Experiment Station seems to be more or less alone in recommending moderately heavy to heavy pruning for red cherry trees. This, however, is for the purpose of promoting a more vigorous terminal shoot growth to obtain a larger percentage of spur-borne fruit buds that are hardier to winter temperatures experienced in some districts of that state.²⁸

4. Soil Management

A. COVER CROPS AND MULCHES

Annual Cover Crops. Most cherry orchards are given clean cultivation from early spring until the crop is harvested, when an annual cover crop is sown. This, in turn, is disced under the following spring. This method of management usually promotes vigorous growth of the trees and leads to heavy yields of fruit. The addition of the organic matter supplied by the cover crop improves the physical condition of the soil and increases the capacity of the latter to hold water. It reduces the amount of erosion in orchards and aids materially in maintaining the fertility of the soil by taking up soluble mineral nutrients which would otherwise leach out. The cover crop helps to mature the wood of the tree during the fall by utilizing the water and nitrates supplied by the soil. It reduces the possibility of winter injury to the roots in the northern states by catching and holding drifting snow. Cover crops also prevent puddling of soils in warm climates where the winter rainfall is heavy and in cold climates that have heavy spring rainfall.

There may be some conditions under which the growing of a cover crop is not desirable. Two orchards in Colorado failed to show improvement under a cover crop system of management during a four-year period because the soil was reduced to the wilting percentage nearly every year when cover crops were grown.⁶

Cover crops that are killed by freezing are preferred in most districts because they do not compete with the trees for nitrogen in early spring. In some warm climates, however, it is desirable to have crops that will grow at low temperatures throughout the winter to provide a higher yield of organic matter.

In general, a suitable cover crop for a cherry orchard is one that

can be seeded at the time of the last cultivation, immediately after the completion of harvest, and that will produce the maximum amount of dry matter. Some growers prefer those that remain upright during the fall and winter so that they will catch and hold leaves and drifting snow. Others place greater stress on the ability of the cover crop to add nitrogen to the soil. Some of the annual cover crops in common usage are rye, rye and vetch, oats, soybeans, Sudan grass, buckwheat, and domestic rye grass. In the northern states, soybeans and Sudan grass may not make sufficient growth if the planting is delayed until after the cherry crop is harvested.

Cover crop use in California is variable. Most growers grow an annual leguminous winter cover crop and practice clean cultivation during the spring and summer months. *Melilotus indica* is the favorite cover but some growers use vetch, bur clover, or the small-seeded horse bean.¹⁵

Permanent Cover Crops. The cherry orchards of England usually are kept in permanent grass. When the trees are young, a ring of soil six or more feet in diameter at the tree trunk may be kept free of grass or the entire area may be cultivated for the first eight to twelve years or six to ten years, respectively, for sweet and red cherry orchards. Thereafter sod is maintained over the whole orchard area, even up to the tree trunks. This is made possible by high headed trees—six and three foot trunks, respectively, for sweet and red cherry trees. The orchards are grazed with enough sheep to keep the grass short or, in some cases, the grass is mowed frequently.¹

The Michigan Experiment Station made a 15-year comparison between red cherries grown in an alfalfa sod and the cultivation-cover crop system of soil management. The trees growing in the sod were fertilized sufficiently to force the trees to make a desired terminal growth and the alfalfa was mowed twice each year and spread under the trees as a mulch. The orchard was growing in a medium-heavy, well-drained, clay loam. The soil moisture content to a depth of five feet in August of the 11th year was 6.8% for the cultivated areas and 9.2% for the sodded area. The difference was due to the greater water runoff from the cultivated area during rains. At the end of 15 years, the trees in the cultivated plots had tops that were nearly twice as large as those under sod management. The total average tree yields were 494 pounds for the sod and 663 pounds for those under cultivation. The sod trees, however, produced good crops and showed that such a system of soil management is possible.³¹

Most well-drained, loamy soils are able to supply moisture for both the trees and sods if the grasses or legumes are shallow-rooted ones that make little growth during hot and dry weather. A suitable sod conserves the fertile surface soil on hillsides that are subject to erosion, increases the permeability of the soil thereby permitting better penetration of rainfall, prevents surface runoff, matures the wood well before the onset of winter, holds snow in winter, and is of great value in reducing rate of cold penetration to roots in winter.³²

Mulching. Competition between the annual or permanent cover and the tree may be reduced substantially by mulching the trees with straw or similar material. The mulch prevents surface evaporation from the soil, increases the water penetration, reduces surface runoff, renders soil nutrients more available and supplies essential nutrients on decomposition.³³

Where straw is used as a mulching material, the rate of application should be enough to provide a six-inch covering over an area slightly larger than the spread of the tree. This may mean two to six or seven tons per acre, the amount depending on the size of the trees.

Table 10 shows that the use of mulches of straw or alfalfa in-

TABLE 10. AVERAGE YIELDS, IN POUNDS PER TREE, OF MONTMORENCY TREES SUBJECTED TO VARIOUS SOIL MANAGEMENT PRACTICES, 1947-1951³³

	No mulch	Sawdust mulch	Straw mulch	Legume mulch	Average
Fescue sod	27.6	18.4	50.7	54.6	37.8
Kentucky blue grass sod	21.6	30.3	61.6	44.6	39.5
Clean cultivation cover crop	58.0	56.7	71.4	76.6	65.7
Average	35.7	35.1	64.6	58.6	

creased production of Montmorency cherries nearly 30% when used with clean cultivation and as much as 100% when used with a permanent sod cover. Such mulches provided greater benefits than any other soil management practice. Sawdust did not provide a satisfactory mulch.

It has been assumed that freshly mulched trees should be provided with greater quantities of nitrogen than unmulched trees, but recent investigations indicate that nitrogen applications need not be increased when a straw or a legume mulch is first applied. As the mulching material ages and decays, it releases nitrogen, making it advisable to reduce the amount applied as a fertilizer.³³

It is evident that there is no one soil management treatment that is best for all situations. The rather general practice of providing clean cultivation during the early part of the growing season and then sowing an annual cover crop appears to be satisfactory for locations that are not subject to erosion. Permanent covers or sods are desirable on many of the locations that are likely to erode and they may be employed in some other orchards. Cherry trees in sod orchards, however, should be mulched with liberal applications of straw or grasses that cover at least the areas under the spread of each tree.

B. IRRIGATION

The cherry may be grown with less water than most other deciduous tree fruits and practically all the eastern crop and much of the crop grown in the western states is produced without irrigation. Soil moisture, however, is definitely a limiting factor in some areas of commercial production and supplementary irrigation must be provided in these districts to grow the crop to maturity. In some areas irrigation must also be provided to enable the trees to go into winter in a satisfactory condition.

The number of irrigations required during a growing season in western districts may vary from one to a half-dozen. The number is determined by the depth of the soil, the rate of transpiration from the trees, the character of the soil, and the normal amount and distribution of rainfall. Soils that are coarse in physical characteristics must be irrigated more frequently than fine-textured ones. It is usually advisable to apply enough water to soak the soil to a depth of four or five feet at each application.

Salts contained in the irrigation water may accumulate in the soil to such an extent that the concentration becomes injurious to trees. Less frequent but heavier applications of water may be necessary in such cases to allow the salts to leach out. The basin or floating type of irrigation is less likely to cause salts to accumulate in the surface soil than the furrow method.¹¹

C. SOIL FERTILIZATION

Trees must obtain from the soil substantial quantities of such elements as nitrogen, phosphorus, potassium, sulfur, calcium, iron, and magnesium and very small amounts of such elements as boron, copper, manganese, and zinc. Other non-essential elements, among several that may be taken up by the plant, include arsenic, chlorine, and sodium.

Major Elements. The elements that are most likely to be deficient in soils are nitrogen, phosphorus, and potassium. A vast amount of evidence indicates that nitrogen is the element that is most likely to give response in both sweet and red cherry orchards, and that the red cherry may be expected to give a more striking response to applications of nitrogenous fertilizer than the sweet cherry.

Annual spring applications of nitrogen to 16-year-old Montmorency trees in the Hudson River Valley increased substantially the numbers of shoots six inches or more in length during the first season. This was accompanied by an equally significant increase in tree-trunk diameter for the three years of observation. All of the treatments that included nitrogen resulted in increases in the average sizes of the leaves. There were no differences in yield due to treatments during the season of the first application but during the second season the trees receiving nitrogen noticeably out-yielded those trees receiving no nitrogen, and the third season's crop continued in the same direction. While the trees receiving phosphorus and potash showed gains over the control, the differences were not significant.²⁷

The data in Table 11 are for a ten-year-old Montmorency orchard growing in a rather infertile, light sandy loam in Michigan. The trees had made little shoot growth and the yields had averaged less than 50 pounds per tree annually. The application of nitrogen resulted in an increase in number of fruit buds per spur, lengthened shoot growth, caused many old spurs to grow into shoots, greatly increased the bearing surface of the trees, and increased the yields strikingly. Nitrogen applications did not influence the number of leaves per spur but it increased the size of spur-borne leaves substantially and the size of shoot-borne leaves to some extent. Trees that received nitrogen produced an average of 2.7 flowers per cluster compared with 2.5 for the non-nitrogen fertilized and non-fertilized trees. The small differences in fruit setting indicate that lack of nitrogen at blossoming time is not a factor in fruit setting. The trees that were fertilized with acid phosphate seemed to give about the same response as the non-fertilized trees in every respect. In this orchard, fall fertilization gave better response in both tree growth and yields than did spring application.²⁶

Nitrogen; phosphorus; potassium; nitrogen and phosphorus; a combination of nitrogen, phosphorus and potassium; and manure were applied to plots of red cherry trees for four consecutive years under semi-arid conditions in Colorado. The non-nitrogen treatments gave

TABLE 11. INFLUENCE OF FERTILIZER TREATMENTS ON VEGETATIVE GROWTH AND YIELD OF MONTMORENCY CHERRY TREES GROWING IN A LIGHT SANDY LOAM²⁵

Treatment	Ave. No. fruit buds per spur formed in		Ave. 1925 shoot growth, in.	Percentage 1924 spurs growing into shoots in 1925	Ave. yield per tree, lb. ^b			
	1923	1924			1924	1925	1925	1928
Sulfate of ammonia	2.7	4.2	4.7	17.8	73	132	15	136
Acid phosphate	1.9	3.0	1.6	1.3	30	80	2	^c
No fertilizer	2.1	3.3	1.9	3.0	37	74	3	^c
Sulfate of ammonia and acid phosphate	3.3	3.7	5.2	15.2	99	138	29	138
Sulfate of ammonia, fall application	^a	4.0	6.7	41.5	31	109	34	151
Sulfate of ammonia and acid phosphate, fall application	^a	4.8	8.3	47.1	50	122	43	161

^a Fertilizer applied in the fall of 1923. Other trees fertilized in spring of 1923.^b Frost caused a partial crop failure in 1926 and a complete failure in 1927.^c The acid phosphate and the no fertilizer treatments were discontinued in the spring of 1927.

four-year average annual yields ranging from 36 to 48 pounds per tree, while the nitrogen treatments ranged from 48 to 61 pounds and the manured plot averaged 61 pounds. The yield increase was reported to be due to increase in set of fruits and increase in numbers of fruits matured.⁶

Increased production was obtained in Wisconsin when either nitrogen alone or a complete fertilizer were applied, but yields from phosphorus-potassium fertilized trees were no better than those of the controls.³⁴

As much as 18 to 25 pounds of sulfate of ammonia was applied to the soil under old red cherry trees for three successive years in Michigan, and while it killed all vegetation under the trees, there was no apparent injury to the roots of the trees. These trees set and matured heavy crops, evenly and early.³⁵ This early maturity confirms Gardner's earlier report²⁶ but Tukey²⁷ and Proebsting³⁶ found that nitrogenous fertilizers delayed maturity of red and sweet cherries, respectively.

At very high intensities of nutrition, in controlled experiments, the nitrogen in the leaves of Montmorency trees was observed to reach a level that was toxic, resulting in reduced growth.³⁷

Nitrogen-carrying fertilizers often increase the size of other kinds of fruits but such a response does not seem to be common in cherries.^{6,26}

The above responses to nitrogenous fertilizers have been reported for red cherry trees. It is not likely that such outstanding results can be expected with the sweet cherry. They seem to grow vigorously and fruit well until they reach an age of 12 to 15 years when the trees, especially those that are somewhat crowded by close planting, may decline in vigor and may even get into a condition of alternate bearing. Schuster¹⁹ says this condition is due to starvation and he recommends an application of 200 to 300 pounds of a nitrogen-carrier such as nitrate of soda or sulfate of ammonia.

Significant increases in the nitrogen and phosphorous contents in leaves of Bing trees followed annual applications of 6 pounds of nitrogen carrier and 7.5 pounds of acid phosphate per tree in the Yakima Valley of Washington. Nitrogen applied alone or in combination with phosphorus gave increases in yield of fruit and terminal growth of shoots but neither of the increases were great enough to be regarded as significant. The applications of nitrogen delayed the ma-

turity of the cherries, reduced the amount of a sub-epidermal breakdown in storage known as pitting of fruits, and gave some indication of a reduction in the amount of mold developing subsequent to harvest. The contention of some growers that phosphorous firms the fruit, hastens maturity, and improves the keeping quality of cherries was not confirmed in the investigations.³⁸

Nitrogen applied in the form of cyanamid in the late spring to cherry trees growing on light sandy or gravelly soils may cause leaf burning and sometimes defoliation if the soil becomes dry. This nitrogen carrier did not cause injury when applied in the fall. Perhaps the cyanamid requires an adequate supply of soil moisture and sufficient organic matter in the soil to convert the nitrogen into a form which may be absorbed by the tree without proving toxic.³⁹

It should not be assumed that nitrogen is the only one of three important elements that need be applied in all cherry orchards. Potassium deficiency has been observed in a number of red cherry orchards in New York, Michigan and Wisconsin.⁴⁰⁻⁴³ The leaves of potash deficient trees may be curled, folded or rolled toward the upper surface and they may show leaf scorch. The leaves of such trees should be analyzed for potassium content. If the potassium content is below 0.75%, dry weight basis, the trees may be expected to respond to applications of potash.⁴² An application of 2 to 2.5 pounds of muriate of potash per tree resulted in increases of 300 to 400% potassium in the leaves.⁴¹

The evidence presented indicates that most bearing cherry orchards may be expected to give favorable response to applications of nitrogen and that the response takes the form of increased growth of shoots and subsequent increase in bearing surface and yields of fruit. Responses from applications of potassium and phosphorus have been of less frequent occurrence but it must not be inferred that they can be overlooked in designing the soil management practice.

The specific needs for individual orchards may be determined by the grower through actual trials in which single elements are applied in varied quantities to individual trees or blocks of trees. It is likely, however, that an even better criterion of elements and quantities of elements that should be added as fertilizers to cherry orchards will be provided by leaf analyses. The leaf analysis method is currently being used in a practical manner with several deciduous tree fruits to indicate the available levels of nutrient elements.⁴³

Minor Elements. The sweet cherry is more likely to show injury from zinc deficiency in the semi-arid districts of California than other deciduous tree fruits. One of the most dependable symptoms of zinc deficiency is the appearance in spring of small, narrow leaves in short rosettes. The leaves may also be mottled with yellow streaks and splashes between the veins. The size of the fruit is reduced on affected trees. It seems to be more prevalent on open sandy or gravelly soils. It may occur in trees that grow on soils having plenty of zinc. In such cases, the zinc is unavailable to the trees.¹¹

Zinc deficiency may be corrected by spraying the trees in winter with zinc sulfate at rates of 200 to 400 pounds per acre every two or three years by dissolving 25 to 50 pounds in 100 gallons of water. Triangular pieces of galvanized iron of 24 gauge may also be driven into the tree trunks and main branches parallel with the grain of the wood. These pieces of metal, about two inches long and three-fourths inch wide, should be used at a rate of four to six for each one inch of tree trunk diameter.¹¹

A chlorotic condition of sweet cherries, due to a deficiency of manganese, has been observed in England. Areas along the margins of the leaves were the first to show evidences of chlorosis. This spread to areas between the veins and the leaves finally became yellow. Spectrographic examination of the leaves indicated serious manganese and possible magnesium deficiencies. Injection of solid manganese sulfate at the rates of 0.25 gram into a one-half inch hole in trunks having a diameter of three inches and up to 100 grams distributed in 20 holes in the trunks and larger branches of trees having a diameter of 20 inches, resulted in full restoration of green color of foliage and a marked improvement in growth and fruiting. Spraying the trees with manganese sulfate gave only slight improvement.⁴⁴

Interveinal chlorosis due to manganese deficiency has been found in New York on Montmorency trees. Leaf samples from trees showing severe chlorosis contained 17 p.p.m. or less manganese and those from trees showing mild symptoms showed 18 p.p.m. or less. The best control measure appears to be an annual early summer spray of manganese sulfate.⁴⁵

A condition of sweet cherries that resulted in hard, shriveled, and blotchy fruit before maturity was improved by an application of 1.5 pounds of borax to the soil under each tree.⁴⁶ Boron deficiency has also been reported for red cherries in Sweden.⁴⁷

Varying the concentration of ten essential nutrient-elements supplied to one-year-old Montmorency trees was found to directly alter the nutrient-element balance in the leaves, except for copper, iron and boron. In most cases, the supply of an elevated concentration of nutrient-elements resulted in increased absorption of these nutrient elements and vice versa.⁴⁸

5. Pollination

Pollination may be defined as the transfer of pollen from dehiscent anthers to the stigma of a flower. The horticulturist, however, usually employs the term in a broader sense to include germination of the pollen grains in the stigmatic juice and growth of the pollen tubes through the style to the embryo sac where fertilization takes place.

Self-pollination is the transfer of pollen from anthers of a flower of one variety to the stigma of a flower of the same variety. *Cross-pollination* is the transfer of pollen from a flower of one variety to the stigma of a flower of another variety. A variety capable of producing viable seeds following self-pollination is *self-fertile* and one incapable of producing viable seeds is *self-sterile*. These two terms refer to seed viability rather than fruit production, but since seed viability and fruit production, as they relate to pollination, are synonymous in the cherry, it seems that they may be used with propriety in a discussion of cherry pollination. When cross-pollination fails to produce a set of fruit sufficient to result in a full crop, the two varieties are *inter-sterile* or partially inter-sterile. If the two varieties are compatible, they are *inter-fertile*.

Sweet Cherry. All varieties of the sweet cherry studied in Europe and America are self-sterile.^{19,49 57} An occasional fruit may result from self-pollination but in no instance has the set approached that necessary to produce a crop. Self-sterility in the sweet cherry is simply a case of incompatibility and is not due to any abnormalities of the pollen or the pistil.

There are several cases of varietal inter-sterility among sweet cherries. Gardner⁴⁹ reported the intersterility of Bing, Lambert, and Napoleon, in 1913. A number of other incompatible varietal combinations have been reported^{49,52,56} but they involve varieties of lesser commercial importance, such as Rockport and Advance and Early Purple.¹⁵ Cross incompatibility in the sweet cherry is always ex-

pressed reciprocally.⁵² In these cases, pollen germination usually takes place but pollen tube growth in the styles is arrested in incompatible combinations.^{52,58}

There are many compatible combinations among varieties of sweet cherries, but the pollination problem is complicated by several factors other than compatibility. Good pollenizing varieties must come into full bloom at the same time as the varieties to be pollinated and they must produce good crops of quality fruit. Some of the varieties of Duke and red cherries are compatible pollenizers for varieties of sweet cherries,^{49-51,59} but it is seldom that a grower would find it desirable to have more than one species in the same block of trees. Such varieties as Black Tartarian, Black Republican, Windsor, Schmidt, Yellow Spanish, Early Purple, and Governor Wood have been mentioned as good pollenizers for other commercial varieties of sweet cherries.^{19,57,59-61} Black Tartarian and Black Republican were early favorites as pollenizers in the Pacific Coast states^{19,57} but more recently Deacon^{59,62} and Van⁶³ assumed first rank because they are better producers of high quality fruit in addition to being pollenizing varieties.

Another complicating factor in sweet cherry pollination is the existence of a number of strains of several varieties.^{19,51,57,61,64} Some of these strains are more satisfactory than others as pollenizers, and, in some cases, strains of a variety are cross-fertile.

If two or more compatible varieties are to be planted in the same orchard, the orchard planting plan may be such as to provide alternate blocks of two or three rows of a variety. If the orchardist desires a minimum number of trees of a pollenizing variety, he may plant every third tree space in every third row to this variety.

Red Cherry. The varieties of red cherries that are grown for commercial purposes are self-fertile.^{50,51,60,65,66} The experimental evidence is amply supported by the fact that growers of red cherries make no provision for cross-pollination. There are, however, a few minor varieties of red cherries that have been reported to be self-sterile or practically so, including some strains of Montmorency,¹⁹ one form of Kentish Red⁵² and Chase, Homer, and Ostheim.⁶⁷

Duke Cherries. Some varieties of Duke cherries will produce fair crops when self-pollinated, but all of them give better fruiting response when cross-pollinated, hence, they must be regarded as practically self-sterile.^{50,51,60,66} Since the pollen of varieties of Duke cherries gives a relatively low percentage of germination,⁶⁰ varieties

of sweet or red cherries should be employed as pollenizers. Such varieties as Napoleon, Schmidt, Windsor, Yellow Spanish, English Morello, and Early Richmond are regarded as satisfactory pollenizers.⁶⁶

Insects and Pollination. Practically all transfer of cherry pollen is done by insects, and the honey bee is the most important insect in making this transfer. This has been demonstrated repeatedly. For example, the quantities of fruit harvested from Montmorency trees open to visits of bees were 10, 11, 20, and 43 times those harvested from trees screened to prevent access of bees.⁶⁵ Substantial differences in fruit set observed in different portions of the same orchard and between orchards in the same locality have been due to differences in bee populations.⁶⁸

Years of heavy crops in Oregon were found to coincide with years having high temperatures during the blossoming season.¹⁹ This is mostly because the honey bee is not active at temperatures appreciably below 65°F. and partly because nectar secretion is most abundant at temperatures between 65 and 75°F.⁶⁹ Bees prefer to work during clear, warm, quiet days and they will not travel great distances if plenty of blossoms having a good nectar flow are near the hives.

6. Growth Regulation Substances

Growth regulating substances may alter the growth and development of plants and their reproductive parts substantially. Sweet and red cherry trees sprayed during early autumn with 2,4-dichlorophenoxyacetic acid and naphthalene acetic acid were delayed in time of abscission of the leaves during the fall and the time of blossoming in spring was delayed several days. However, the substances caused injury to twigs, spurs, buds, and floral parts that greatly outweighed any advantages that were gained.

Floral parts, such as sepals, petals, and anthers, were bent toward the axes of the individual flowers and this was accompanied by a narrower and stronger development of the vascular system. The pedicels of the flowers were substantially thicker than those produced by untreated trees. The fruits borne by the treated trees were larger than those on untreated trees and were elongate and pointed at the apex. The skin was lighter in color and thicker than is normal for the varieties. The juice of the fruits was lighter in color and of poorer

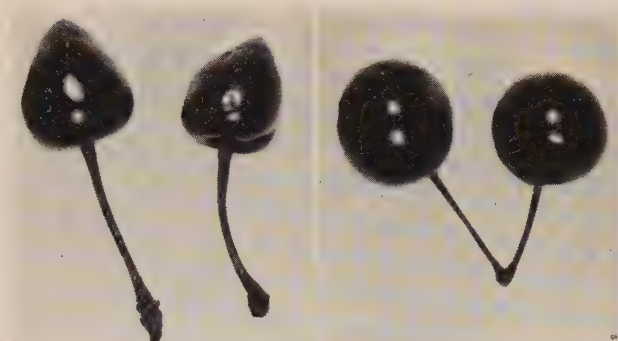


Figure 22. The fruits produced by Montmorency trees (left) sprayed with 2,4-dichlorophenoxyacetic acid or naphthalene acetic acid during the previous September are elongate and pointed at the apex. Normal fruits are shown at right.⁷¹

flavor than that for normal fruits, even though the treatment caused an increase in dry matter and total sugars. The pits of the fruits were above normal in size and they were conspicuously rough.^{70,71}

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DISEASES AND INSECTS AND THEIR CONTROL

1. Orchard Diseases

Any departure from the normal may be called a disease. Thus, such a functional disorder as winter sunscald may be termed a disease. The horticulturist usually thinks of diseases as disturbances caused by either infectious principles or plant parasites. A virus, such as cherry yellows, that can be transmitted from diseased to healthy plants is an example of an abnormality resulting from an infectious principle. There are many diseases of the cherry that are caused by parasites such as fungi or bacteria. Only the more important ones will be treated briefly in the following paragraphs.

A. DISEASES CAUSED BY FUNGI AND BACTERIA

Leaf Spot. The disease caused by *Coccomyces hiemalis* is known by such names as "shot hole," "yellow leaf," "yellow," and "leaf blight," but the preferred name seems to be "leaf spot." Red cherry trees are much more susceptible to the attacks of the fungus than are the sweet cherries.

The fungus causing leaf spot overwinters in dead leaves. Primary inoculation comes from ascospores that are discharged abundantly as the leaves begin to dry and the air temperature in spring approaches 60°F. This may begin before the trees blossom and may continue through a period of six to seven weeks.¹ These spores are carried to new leaves by wind or air currents where they germinate and in time produce conidiospores that spread the fungus to other leaves.²

The initial minute purple or reddish spots on the foliage enlarge and become brown or brown surrounded by a reddish-brown zone. The dead tissue may drop out, giving a "shot hole" appearance to the leaves. The leaves may then become yellowish or chlorotic and drop prema-

turely. Lesions on stems and fruits resemble injury caused by lead arsenate.³

Leaf spot is regarded as the most destructive disease of the red cherry in the Great Lakes states. It has caused the death of a great many trees by making the trees susceptible to winter injury through summer defoliation. Early season defoliation results in small, improperly colored fruits that are sour and unmarketable as fresh fruit and unacceptable at canning factories.^{1,3-5}

Leaf spot is not epidemic every year. The development is controlled by such weather factors as temperature and the amount and the distribution of rainfall. Growers are therefore likely to become lax in control measures after two or three years during which no serious damage occurs. Then, when conditions become favorable for leaf spot development, an inadequate spray program results in very serious damage to both the current crop and the trees.²

Such fungicides as Bordeaux mixture and lime-sulfur were used for many years for the control of leaf spot but they have recently been replaced by proprietary copper compounds and some of the organic fungicides (dithiocarbamates). They should be used as directed by the manufacturers and local agricultural experiment stations.^{1,6 11}

Brown Rot. One of the most damaging phases of the brown rot is the rotting of the ripening or ripe fruit. Sweet and Duke cherries are especially susceptible, but the red cherries are by no means immune to the disease. Very serious losses may occur when hot and humid weather develops at harvest time.

Brown rot was formerly thought to be caused by one fungus but it is now known that there are two species of fungi in America that cause the disease. They have been known as *Sclerotinia fruticola* and *S. laxa* but they recently have been called *Monelinia fruticola* and *M. laxa*.

Monelinia fruticola is more widespread geographically. It may infect the blossoms, causing them to hang limp and blasted on the tree, and these blighted blossoms may provide a source of infection for the fruits at ripening time. Small, circular brown spots develop on the infected fruits and enlarge to involve the whole fruit. Powdery, light brown or gray masses of spores appear on the rotted areas to spread the fungus rapidly to other fruits. The fungus lives over winter in mummied fruits that are largely fungus tissue.^{10,12} These mummied fruits should be knocked off the trees after harvest to reduce the source

of infection in the following spring and summer. The value of the practice of some growers in burying the fruits is questionable.

Monelinia laxa is more prevalent in Pacific Coast areas, where persistent cool, wet weather in spring favors its development, than it is in other areas. However, it has been found in some localities in Michigan and in Wisconsin. This fungus lives over winter in spurs and twigs. It causes decay of blossoms and spurs but does not cause as much damage to fruits as does *M. fruticola*.

Spraying with Bordeaux and monocalcium arsenite before the buds break followed by Bordeaux or a naphthoquinane in early bloom is insurance against the development of the disease.¹⁰

California blight is caused by a fungus known as *Coryneum beijerinckii*. The fungus may attack the leaves, causing spots and subsequent "shot-holing"; it may cause cankers on twigs and limbs, or it may cause a spotting and rotting of the fruit. Small areas of flesh on the diseased fruits dry to the stone and may enlarge to involve the whole fruit. Spraying with bordeaux as soon as the leaves are shed from the trees and possibly again about one month before blossoming should provide control.¹³

Bacterial gummosis may be held in control by planting resistant Mazzard or Mahaleb seedlings in the orchard to form the framework for the trees, and then grafting the main limbs to the desired varieties.^{11,14} Growing alfalfa as a permanent cover crop seems to make the trees less subject to gummosis in parts of California and some growers believe that spraying the tree trunk and main branches during the late fall or early winter with 8-8-50 bordeaux lessens infection.¹¹

Mushroom root rot or oak fungus, caused by *Armillaria mellea*, may result in serious injury to cherry trees planted on recently cleared land in Pacific Coast regions and is not unknown in certain eastern areas of production. This wood-rotting fungus is both a parasite and a saprophyte that causes the death of the roots. It spreads slowly from root to root. Little can be done to eradicate the fungus once it becomes established in an orchard. Two ounces of carbon disulfide injected into the soil at 18-inch intervals in staggered rows, and to a depth of six to eight inches, during a dry, warm period when the soil contains little moisture may destroy the fungus in light and moderately textured soils. A water seal, made by spraying the surface of the soil or by a light irrigation, is recommended to prevent loss of the gas.¹¹

Cherry mildew is caused by a fungus known as *Podosphaera*

oxyacanthae, which may attack the leaves. It is readily controlled by the spray treatments recommended for the control of leaf spot.

B. VIRUS DISEASES

Virus diseases of the cherry were not recognized as such prior to 1930, but more than 30 virus diseases or disorders with virus-like symptoms were recorded during the ensuing 20 years and new ones are being discovered rapidly. All 30 diseases affect the sweet cherry and about two-thirds of them are known to infect the red cherry.¹⁵

Virus diseases are caused by very small parasites that live and multiply in the host plants. Some of them, such as *cherry yellows* of the red cherry and *buckskin* of the sweet cherry, are of much concern in the industry. A few of them are widespread, but some are more or less localized (*mottle leaf*). *Albino* is one of the virus diseases that kills trees while others, like cherry yellows and *X-disease*, reduce production or, in case of *pink fruit* and *little cherry*, produce unmarketable fruit. Some virus diseases spread rapidly, while others spread slowly, and most of them may be spread through the distribution of nursery stock. Perhaps of most concern is the fact that none of these virus diseases can be controlled by spraying.

The geographic distribution, economic importance, hosts, symptoms, transmission and control measures for the many virus diseases affecting the cherry in North America are adequately treated in a handbook prepared by the leading virus pathologists. This handbook also includes the more important literature citations for each of the diseases.¹⁵ A discussion of even the most important individual virus diseases does not therefore seem to be justified in this chapter.

There are two general methods for controlling virus diseases: prevention by exclusion and removal of diseased trees from the orchard. New plantings should be made with trees that have been grown from buds taken from disease-free trees. Many nurseries are making every effort to propagate cherry trees from trees that have been certified to be apparently free of disease.

Where isolated diseased trees or small groups of trees are present in an orchard, the trees should be removed to retard the rate of spread in the orchard. Where a substantial portion of the orchard appears to be infected with a virus such as that causing cherry yellows, it may be desirable to maintain the orchard until such time as it may become unprofitable, when the whole orchard may be destroyed. How-

ever, it is doubtful if such a practice is desirable to eliminate a trouble such as little cherry.

Control of insect vectors is a third means of retarding the spread of virus diseases, though the vectors are known for only a few of the diseases.

2. Orchard Insects

There are some 40 species of insects that may cause more or less damage to cherries by attacking the foliage, fruit, or woody portions. Only a few of these are important in commercial orchards that are given reasonably good management. Some, like the cherry fruit flies and the black cherry aphid, are specifically cherry insects, while others, such as the curculio, the scales, slugs, caterpillars, grasshoppers and climbing cut worms, may infest a number of species of tree fruits.

Cherry Fruit Flies. The worms in cherry fruits may be the larvae of the curculio or of the cherry fruit flies. There are two species of cherry fruit flies. The dark or black one is *Rhagoletis fausta* and the white-banded fly is *R. cingulata*. Adult flies emerge in the late spring and early summer from underground parchment-like cases and fly to the trees where the females feed and lay eggs in small slits in the fruits about a week after emergence. The eggs hatch into white, footless maggots that burrow through the fruits and, when mature, drop to the ground where they work their way into the soil and change to the pupal or resting stage to remain until the following spring.¹⁶

The fruit flies are the most troublesome insects infesting red and sweet cherries in Northern United States and Canada. The presence of the maggot is often unsuspected until the fruits are to be sold. Infested fruit has a lower specific gravity than sound fruit and will float when the cherries are agitated in soaking tanks of processing plants. They may then be skimmed off.¹⁶

Insecticides are effective only when the adult females are feeding and the first spray should therefore be applied before the flies begin laying eggs. Applications of methoxychlor, ground derris or rotenone may need to be repeated at seven- to ten-day intervals. These materials leave no harmful residues.¹⁰

Curculio. The larvae of the plum curculio, *Conotrachelus nemophar*, may infest cherry fruits in portions of the United States and Canada east of the Rocky Mountains. The adult insect winters as a

dark brown snout beetle under leaves, in fence rows, in piles of stones, and similar places in or near orchards. It flies to the trees about blossom time to feed and to deposit eggs in the fruit. A crescent shaped slit extends under each egg to provide a flap. The egg hatches in a few days to a grayish-white, legless larva, having a curved body and a brown head. When the larva matures it leaves the fruit and moves into the ground, where it changes to the pupal stage and then to the adult beetle. In the more southern areas of production, a second generation may result, but north of latitude 39°, there is only one generation.¹⁷

Most curculio infestations are controlled by two arsenical sprays, one at shuck fall and the other about two weeks later.

Mineola Moth, *Mineola scituelia*, passes the winter as a chocolate brown larva in a small silken case in the crotches of twigs and spurs. At the early green-tip stage of buds, the larvae feed inside the swelling buds and spin a silken web around the bud clusters. Two summer generations of larvae bore into the cherries. Larvae entering the fruit near harvest time have been found in processed cherries. Dinitro sprays when the trees are dormant or parathion applied at the green tip, pre-blossom and petal fall periods give commercial control.¹⁰

Scale Insects. San Jose scale (*Aspidiotus perniciosus*) is a serious pest of the sweet cherry, especially young trees, but it seldom causes appreciable damage to red cherry trees. The latter, however, are sometimes infested with Forbes scale (*Aspidiotus forbesi*) which resembles San Jose scale. Both kinds of scale appear as grayish, thin, flaky scales massed on the bark of branches and twigs. They cause a general decrease in vigor of the trees, and, if uncontrolled, may cause death of the trees, starting with the death of terminal shoots.¹⁷ These scale insects are readily kept in check by oil emulsion sprays applied before the buds show green in the spring.¹⁸

Case Bearer. These small grayish brown worms are enclosed in tiny, brownish-gray, tough, silken cases about one-fourth inch in length. They drag their cases with them as they feed on leaves, buds, and fruits, eating out numerous small holes. There are three species known as *Coleophora prunella*, the Cherry Case bearer, *C. fletcherella*, the cigar case bearer, and *C. malivorella*, the pistol case bearer. They may be found in midwestern and eastern orchards.

The case bearer winters in the larval stage inside cases attached to the bark of trees. They begin feeding about the time the leaves unfold and soon become full grown. They then pupate and later emerge

as small gray moths about one-half inch long. The adults deposit eggs on the underside of leaves. Larvae appear in late summer and feed on the leaves until fall, when they migrate to the twigs and branches to spend the winter.¹⁷

A dormant spray of DN compounds, dinitro salts of phenols and cresols at manufacturers' recommendation is recommended.¹⁰

Aphids. There are many kinds of aphids or plant lice that may infest the cherry, chief of which is the black cherry aphid, *Myzus cerasi*. The latter causes the leaves to curl badly, become dwarfed, and covered with a honeydew secreted by the aphids. Aphids effect the size and flavor of the fruit and make it sticky and unattractive.

Spraying, when the trees are dormant with DN compounds will destroy the eggs of aphids. The black cherry aphid may be controlled on the red cherry after the dormant season by spraying with dichlorodiphenyl-trichloroethane (DDT) or with nicotine sulfate.¹⁰

Other Insects. There are a number of other insects, such as grasshoppers, climbing cut worms, the various kinds of caterpillars, leafhoppers, and borers, that may infest cherry orchards. Leaf-eating insects are generally controlled by the arsenical sprays. Grasshoppers and climbing cut worms are readily controlled with chlordane. Leafhoppers are controlled by a contact insecticide such as nicotine sulfate or with DDT. Borers that cause "pin holes" in branches and twigs may be controlled by providing sanitary cleanups and by invigorating the trees through fertilization. They usually attack only weakened trees in the orchard.

3. Spraying Materials

The cherry is rather tolerant of the insecticides in common usage but plant pathologists and pomologists have been much concerned with the various plant responses associated with the application of fungicides to cherry trees. This accounts for the seemingly disproportionate amount of space devoted to fungicides in the discussion that follows.

Copper Sprays. Bordeaux mixture has long been used as a fungicidal spray for cherries. It is very effective in controlling leaf spot but there are several objections to the use of it in cherry orchards after blossoming. Dutton and Wells¹⁹ were the first to report that Montmorency cherry trees sprayed with lime-sulfur produced fruits that were 3 to 22% larger than those sprayed with Bordeaux and that this decrease

in size of fruit borne by Bordeaux-sprayed trees is due to increased transpiration of the foliage. This has been substantiated by the work of others.^{7,8,20-23} This effect is intensified during seasons characterized by high temperature and low relative humidity.²¹ Proprietary copper compounds and weak Bordeaux give less reduction in size of fruit than Bordeaux at the usual concentration of 4-6-100.^{7,22}

Cherry fruits from trees sprayed with Bordeaux, especially the higher concentrations, are darker in color and contain larger percentages of sugars and total solids than those sprayed with lime-sulfur or those from unsprayed trees. In one experiment the percentage of total solids in fruits from trees sprayed with 4-6-100 Bordeaux ranged from 19.2 to 20.7, while fruits from trees sprayed with either 2-3-100 Bordeaux or proprietary copper compounds ranged from 16.5 to 18.0% solids. The differences may be attributed to differences in transpiration rates. Measurements of transpiration rates from potometers for 55 leaves during a 48-hour period following several spraying treatments were as follows for different treatments: lime-sulfur, 136 c.c.; Cupro K, 123 c.c.; Tennessee 26 and lime, 129 c.c.; Bordeaux 2-3-100, 170 c.c.; and Bordeaux 6-8-100, 208 c.c.²²

Bordeaux may cause serious copper injury to foliage and subsequent defoliation in some years. This injury first appears as an upward curling of the leaves followed by purpling or browning of the underside of veins and then a yellowing and dropping of the leaves.⁶ The condition is likely to be more pronounced in seasons of low rainfall. Such defoliation may amount to as much as 70% by late September or early October.^{6,7,25} The proprietary copper compounds are less effective in disease control than Bordeaux but they cause less injury to foliage than Bordeaux.^{6,7,10}

Spraying materials may affect the photosynthetic activity of cherry leaves. Trees sprayed with one of the proprietary copper compounds (Cupro K) and unsprayed trees produced significantly greater amounts of photosynthate per day than trees sprayed with Bordeaux, lime sulfur or a copper compound known as Coposil.²³

Sulfur Sprays. Two types of foliage injury on red cherry trees are associated with lime sulfur. One is characterized by irregular, dead, dry areas that form in leaf tissue between the veins and along the midrib. These dead areas fall out in a few days. This trouble seems to be associated with high temperature. The other is a rapid yellowing of leaves and heavy defoliation within a few days after application of the

spray. It is thought that the lime-sulfur is absorbed through ruptured areas caused by leaf spot since it is common only on trees having leaf spot infection.^{6,24} Elemental sulfurs do not possess the caustic properties of lime sulfur and are less efficient in killing established fungi.¹⁰

Spray materials may also influence the internal structure of the leaf. An investigation in Michigan showed that leaves of the Montmorency cherry sprayed with lime-sulfur had a thicker layer of palisade cells than those sprayed with either one of the proprietary coppers or one of the dithiocarbamates. Likewise, parathion sprays resulted in greater depth of the palisade layer than such insecticides as benzene hexachloride or arsenate of lead. This is significant because the depth of the palisade layer is correlated with rates of photosynthesis and growth. However, the inability of lime sulfur to control heavy infestations of leaf spot and its other limitations outweigh the benefits just cited.²⁶

In view of the above comments relative to fungicides, it is evident that the cherry grower should rely on the newer organic fungicides (dithio-carbamates) or the proprietary coppers rather than lime sulfur or Bordeaux mixture for the control of fungus diseases that are controllable by spraying.

4. Spraying Schedules

A spraying schedule designed for one area of production may be entirely unsatisfactory for the same varieties of cherries grown in an adjacent state or region. Brown rot may be the principle problem in one district, aphids may be the most troublesome pest in another region of production, and there may be several serious diseases and insects in another area. State agricultural experiment stations or county agricultural agents should be consulted for specific recommendations for the different areas of production and for the different groups of cherry varieties.

5. Oil-Wax Emulsion Sprays

Mention has been made of the susceptibility of the cherry to water deficits due to foliar transpiration that result in reduced size of the fruit, and evidence was produced earlier showing that certain fungicidal materials cause increases in transpiration and further reduction in

size of fruit. Preliminary investigations in Michigan showed a seven percent increase in weight of fruit from the use of one application of an oil-wax emulsion containing a fungicide. When two and three applications of a one percent emulsion were made, the increase amounted to 15 and 35%, respectively.²⁷

Subsequent work showed that the increase in weight of the fruit from three plots receiving two applications of the oil emulsion ranged from 7.6 to 12.9% and averaged 9.8%.²⁸ Still later, in the same state, the increases in size of fruit attributable to the oil-wax emulsion were as follows: Windsor, 23.6% ; Black Tartarian, 14% ; Montmorency, 12, 7, and 7.5%.²⁹

When the same wax emulsion was used in California, no increases in size of individual fruits of Black Tartarian, Lambert, and Bing cherries were obtained. The differences in responses in California and Michigan may have been due to the greater depth of soils and the more extensive root systems in California, and the fact that irrigation in this state eliminates prolonged periods of soil water deficits, whereas in Michigan a more restricted root system may deplete soil moisture rapidly if not replaced by frequent rainfall.³⁰

During the course of the experiments in Michigan, there was some indication that red cherries that had been sprayed with the wax emulsion did not possess satisfactory quality. Subsequent work in both Michigan and Wisconsin showed that the increases in size of fruit and in yield were accompanied by lower quality of fruit as indicated by soluble solids and total solids content of the fresh fruit and by lower drained weight of the canned cherries. Furthermore, it was found that the adherence of spray residue to fruit was serious when the wax emulsion was combined with an organic fungicide in two applications.^{31,32}

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**CHEMICAL AND PHYSIOLOGICAL
CHANGES IN CHERRY FRUITS**

Few studies have been made of chemical and physiological changes that occur in cherries prior to maturity. Several investigators, however, have made analyses of cherries after harvest. Since these fruits undergo negligible chemical changes after harvest, some of the assays of harvested fruit may be used to indicate the chemical composition at maturity.

Investigators have based chemical composition of cherries on the pit-free or edible portions of the fruits and have expressed most of the analyses in terms of percentages or grams of a constituent in 100 grams of fruit pulp.

1. Solids

Total Solids. Seasonal trends for total solids in the Napoleon and Montmorency varieties are presented in the Table 12. Napoleon shows a maximum total solids content at the time of whitening. A decrease in percentage of total solids occurred during the next week, and this was followed by an increase during the final 17 days, or until the fruits were ripe. The Montmorency reached maximum solids content of 25.14 and 23.69% at, or prior to, the time of whitening in the two years for which data are supplied. This was followed by very substantial reductions in total solids (9.29 and 7.09%, respectively) and final increases during ripening to 16.70 and 13.57%, respectively, for 1928 and 1929. Other varieties studied by Caldwell¹ show similar seasonal trends.

Hartman and Bullis² determined total solids in Napoleon fruits at three-day intervals during the final 21 days of maturity and found a

TABLE 12. CHANGES IN CHEMICAL COMPOSITION OF NAPOLEON AND MONTMORENCY CHERRIES¹

Date	Av. diam., mm.	Color or condition	Ave. wt., g.	pH	Active acidity Ch	Acidity of fresh juice, %		Sugars		Titratable acidity, %	Astringent substances		Solids			
						Total, %	Reducing, %	Sucrose, %	Total, %		Non-tannin, %	Soluble, %	Total, %			
1928 Series Napoleon																
May 5	3.5-8	—	.121	4.74	.0000182 N	—	.629	.98	1.50	2.48	.632	.490	.332	5.100	6.522	11.622
May 15	10-12	—	.94	4.40	—	.629	2.64	.20	2.84	.417	.458	.358	5.320	6.425	11.745	
May 21	10-14	—	1.04	4.24	—	.717	1.77	.39	2.16	.530	.446	.273	4.640	9.724	14.364	
May 28	12-15	Whitening	1.66	4.05	—	.817	2.46	.46	2.92	.622	.358	.268	4.920	10.101	15.021	
June 5	16-18	Red	3.23	3.60	—	.918	5.15	.52	5.67	.752	.207	.135	7.720	1.845	9.565	
June 22	19-20	Ripe	4.19	3.42	—	—	7.98	.77	8.75	.634	.183	.108	13.120	1.339	14.459	
June 18	—	Canning ripe	—	3.38	.0004169 N	—	—	—	—	—	—	—	—	—	—	
1928 Series Montmorency																
May 8	2-4	—	.231	4.74	.0000182 N	—	.877	2.69	.50	3.19	.604	.861	.412	6.280	9.013	15.293
May 16	6-8	—	.590	4.23	—	.964	1.49	.24	1.73	.682	.701	.320	4.960	13.366	18.326	
May 21	8-12	—	.635	4.11	—	1.092	1.24	.40	1.64	.717	.670	.346	5.040	20.095	25.135	
May 28	—	—	.735	4.21	—	.00123 N	1.641	1.10	.93	2.03	1.100	.782	.348	4.960	4.333	9.293
June 5	10-14	White	1.22	3.56	—	1.990	8.62	.84	9.46	1.645	.438	.187	15.320	1.375	16.695	
June 18	—	Full red	3.51	2.91	—	—	—	—	—	—	—	—	—	—	—	
June 22	—	Canning ripe	4.40	3.06	.000871 N	—	—	—	—	—	—	—	—	—	—	
1929 Series Montmorency																
Apr. 27	6-9	—	—	4.26	.00005495 N	—	2.13	.04	2.17	.833	.968	—	5.00	6.082	11.028	
May 6	—	—	—	4.08	—	—	2.15	—	2.15	.961	.743	—	5.36	12.401	17.761	
May 14	—	—	.83	4.08	—	—	1.28	—	1.28	.941	.864	—	5.44	18.251	23.691	
May 22	—	—	.90	3.91	—	—	.61	.03	.64	.927	.575	—	3.64	15.364	19.004	
May 27	—	Whitening	1.25	3.35	—	—	1.76	.04	1.80	.954	.346	—	3.80	3.288	7.088	
June 3	—	—	2.17	3.21	—	—	3.98	.02	4.00	1.222	.335	—	6.52	1.886	8.406	
June 7	—	Light red	3.40	3.01	.0009772 N	—	7.13	—	7.13	1.626	.407	—	10.92	1.286	12.206	
June 11	—	Full ripe	—	3.10	—	—	8.12	.18	8.30	1.740	.393	—	12.16	1.406	13.566	

gradual increase from 11.8% to 24.2%. It appears that this period approximates the final 17-day period of Caldwell for this variety since the increase is very marked and is essentially a straight-line trend.

Bohart⁸ found a similar increase in solids content during the period that the Napoleon cherry changes from yellow green to ripeness and also noted that cherries harvested from the outer portions of the tree have solids contents that are substantially higher than those of fruits produced in the interior portions of the tree (Table 13). This latter condition seems to be associated with differences in maturity of fruits; cherries borne on the outer portions are more mature than those from interior parts on the same date.

Table 12 shows that the high percentage of total solids at, or prior to, the time of whitening, is due to a rapid increase in percentage of insoluble solids, which reach maxima of approximately 10% and 18 to 20%, respectively, for Napoleon and Montmorency. The percentages of insoluble solids then decline rapidly to approximately 1.3 to 1.4% at full ripeness for two varieties.

Soluble Solids. The solids of the expressed raw juice of the fruits are termed soluble solids. They usually are approximated by means of a Brix or Balling scale hydrometer. The readings on such hydrometers must be corrected to a temperature of 60°F.

Figure 24 shows that the total soluble solids of the expressed juice of Napoleon increased from 14.5% to 25.9% in three weeks, as indicated by readings made with a Balling hydrometer. Hartman and Bullis² state that Napoleon, as well as Bing and Lambert, are sufficiently mature for eating when the juice gives a Balling test of 20%. This reading was attained by June 19 with Napoleon. During the next six days the percentage of soluble solids increased from 20.1 to 25.9%, representing a gain of nearly 29% after the fruits had reached a usable stage of maturity. This increase in soluble solids is associated with an equal improvement in quality of fruit. Such varieties as Black Tartarian and Governor Wood are sufficiently mature for eating when the Balling test shows 16% soluble solids, while the Black Republican variety should have a test of 22%. The season influenced the rate of increase in total soluble solids in the juice of a variety. The Napoleon variety showed as great an increase in soluble solids in three weeks in one year as occurred in five weeks in another season.

Table 14, based on more than 800 samples of Chapman, Burbank, Black Tartarian, and Bing cherries collected at approximately three-

TABLE 13. CHEMICAL CONTENT OF NAPOLEON CHERRIES HARVESTED FROM INSIDE AND OUTSIDE PORTIONS OF TREE³

Portion of tree	Color of fruit	Harvest date	Ave. wt. of fruit, g.	Solids, %	Ash, %	Nitro- gen, %	Ash alkalinity	Alkalinity No.	Acidity as citric, %	pH	Brix
Inside	Yellow-green	June 11	5.64	10.92	.477	.252	59.2	12.4	.75	3.63	9.5
Outside	Slight blush	June 11	6.90	14.78	.486	.223	61.9	12.7	.87	3.60	14.1
Inside	10% blush	June 20	7.59	14.81	.504	.264	61.5	12.2	.86	3.65	14.5
Outside	50% blush	June 20	7.90	17.61	.523	.244	65.5	12.5	.91	3.66	17.0
Inside	70% blush	July 12	8.12	19.78	.576	.307	71.4	12.4	.82	3.79	19.5
Outside	80% blush	July 12	8.20	21.76	.621	.299	79.3	12.8	.86	3.83	21.7

TABLE 14. AVERAGE PERCENTAGE OF SOLUBLE SOLIDS IN CHAPMAN, BURBANK, BLACK TARTARIAN, AND BING CHERRIES AT DIFFERENT COLOR STAGES, CALIFORNIA, 1941⁴

Variety	Color of Fruit					
	Mottled, yellowish- red	Solid, pinkish- red	Solid, light- red	Solid, medium- red	Solid, dark- red	Black
Chapman	10.5	11.5	11.6	12.9	14.4	17.4
Burbank	11.4	12.1	13.0	14.2	16.5	19.5
Black Tartarian	11.7	12.3	13.2	14.9	17.2	20.3
Bing	14.9	15.2	16.4	17.3	20.2	26.8

day intervals from selected orchards in Northern California, shows a consistent relationship between percentage of soluble solids and color development. The Bing cherries were consistently three percent higher in soluble solids than either the Burbank or Black Tartarian varieties, and the latter two varieties averaged one to two percent higher than the Chapman. The solid light-red stage of development is the minimum stage of development for harvest of these varieties in California. No significant differences in the level of soluble solids for the same variety as grown in the different districts of commercial production were noted.

The average daily increases in Brix readings for the expressed juice of Montmorency fruits during 18 to 22 days prior to maturity in Wisconsin were 0.19, 0.135, and 0.24, respectively, for 1932, 1933 and 1934 (Figure 23). The lowest rate of increase, as well as the lowest maximum Brix reading attained, was in 1933 when the cherries grew to large size. The rates of increase were rather uniform except for four days in 1933 when a decrease occurred during a period while the fruits were making a high rate of growth. Brix readings were inversely proportional to the size of the fruits or the rate of growth of the fruits.

It was shown in the preceding chapter that fungicidal sprays may cause substantial differences in the soluble solids content of Montmorency cherries. Variations of two percent with different sprays were common in Pennsylvania and differences of as much as six percent have been observed. The highest solids content were in fruit from trees sprayed with Bordeaux mixture, a somewhat lower content resulted when proprietary copper sprays were applied, and the lowest content followed applications of the organic spraying materials that do not dwarf the fruit.⁶ Similar observations were made in Michigan.^{7,8}

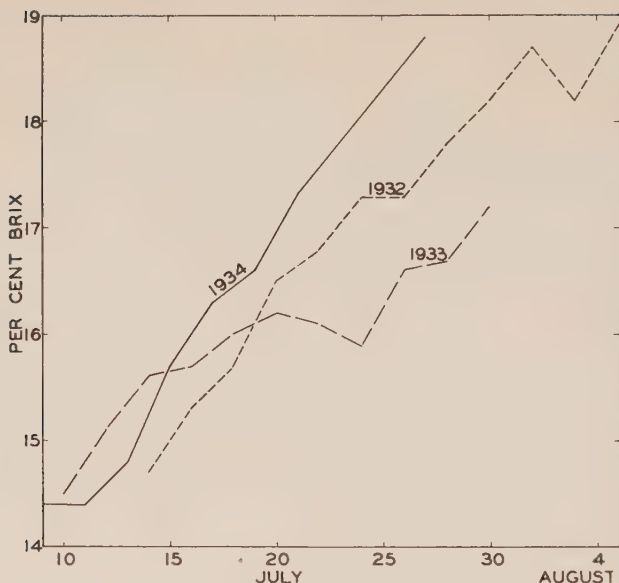


Figure 23. Trends in Brix hydrometer readings for the expressed juice of Montmorency fruits during 18 to 22 days prior to maturity.⁵

The following conclusions may be formulated from the available data: The soluble solids content of cherry fruits remains at a low level until about the time the fruits begin to develop color. Soluble solids accumulate very rapidly during the period of color development and continue to increase at a substantial rate after the fruits attain an edible stage of development. There is a close correlation between the increases in soluble solids and color. The rate of increase, as well as the ultimate amounts of soluble solids developed, varies with season of production. The percentage of soluble solids tends to vary inversely with size of fruit. Varieties differ substantially in soluble solids content. The kind of spray materials applied in the orchard may cause substantial variations in the soluble solids content.

2. Carbohydrates

Approximately 85 to 87% of the total solids in the edible portion of the cherry is carbohydrate material and it ranks high among fruits in utilizable carbohydrates.⁹⁻¹²

A. SUGARS

Total Sugars. A close relationship exists between the seasonal changes in percentages of total soluble solids and the percentage of total sugars. Table 12 shows that the percentage of total sugars in Napoleon increased from 2.16 to 8.75% during a period of 15 days prior to the attainment of ripeness, but during this period the percentages of total soluble solids that were sugar increased from 47 to 67%. The percentages of sugars in Montmorency fruits increased from

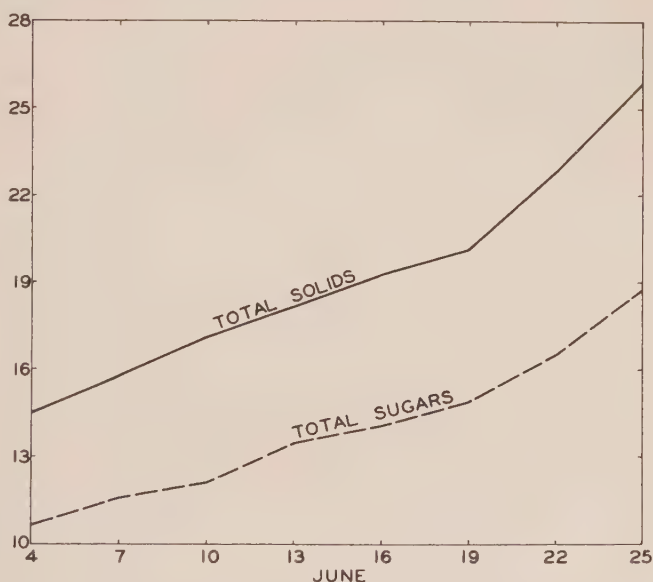


Figure 24. Percentages of solids (Balling test) and total sugars in raw juice of Napoleon cherries during ripening in Oregon in 1926.²

1.64 on June 5 to 9.46 on June 22, 1928, and from 0.64 on May 22 to 8.30 on June 11, 1929. Only 18% of the soluble solids were sugars on May 22, 1929, compared with 68% at full maturity, nearly three weeks later.

Figure 24 shows a close relationship between total solids in the expressed juice as determined by the Balling hydrometer, and total sugars. Sugars increased from 10.6% to 18.9% during the three weeks, but the increase was more rapid during the last six days when the fruit

was attaining full ripeness. Thus, sugar content is closely correlated with maturity and with quality.

The sugar content of the expressed juice of Bing, Lambert, and Victor at full ripeness was found to be 21.3, 17.0, and 17.5%, respectively, in British Columbia. The more mature fruits showed further increases, due in part to some decrease in weight of fruits. Fruits harvested when the juice contained only 16% sugar had poor flavor, became unattractive shortly after harvest, and shriveled in storage.¹³ A later report from the same province states the edible portions of Bing, Lambert and Napoleon must have a minimum of 14, 13 and 12% total sugars, respectively, for good quality and that there is no significant change after harvest unless the fruits lose moisture.¹⁴

The following increases in sugar content were obtained in Ontario during the week before attaining optimum maturity: Windsor, 12%; Victor, 12%, and Montmorency, 11%.¹⁵ Similar trends are reported for varieties in Europe,^{16,42} during the ripening period.

The available data seem to indicate a rather close correlation between the percentage of soluble solids and the percentage of sugars in cherry fruits. However, as the fruits approach full maturity, increasing proportions of the soluble solids are sugars. The percentage of sugar in the fruits may nearly double during the three weeks prior to full ripeness. Varieties vary in sugar content but, in general, the expressed juice of a sweet cherry should have a sugar content of at least 16% to possess a good dessert quality.

Kinds of Sugars. Table 12 shows that 82% of the total sugars in Napoleon on May 21 were reducing sugars and that this increased to 91% at full ripeness, approximately one month later. Some increase in sucrose occurred during this period but the amount at maturity was only 0.77%. However, when the fruits were very young (48 days prior to full ripeness) they contained 1.50% sucrose. This seasonal trend characterizes other varieties of cherries included in the investigation. However, a smaller proportion of the sugar in Montmorency fruits was found to be sucrose than was the case for sweet varieties.

Some investigators have indicated the presence of levulose and dextrose in cherries but the amounts are negligible. In general, investigators have reported sucrose in ripe cherries to range from zero to slightly more than 1%. In other words, the available data seem to indicate that at least 90% of the sugar in ripe cherries is reducing sugar and that the proportion may approach closely 100% in some cases.^{1,17-20}

B. POLYSACCHARIDES

Starch is not present in mature cherries and apparently there is not much of any other substance, such as sorbitol, that may change to sugar.^{9,21}

Pentosans in cherry fruits are reported as decreasing from about six percent to three percent during the ripening period.²² This is assumed to be on a dry-weight basis since another report gives 0.16% as the pentosan content of a heart cherry.¹⁹ Pectic substances in unripe and ripe cherries were found to be 11.4% and 4.3% (dry weight basis), respectively,^{22a} and the average pectic acid content of four samples of cherries is reported to be 0.35% (fresh weight basis).^{22b} The calcium pectate found in 15 samples of "red" and 14 samples of light-colored cherries were 0.28% and 0.31%, respectively.^{22c}

Cherries contain very little crude fiber. The available reports indicate a range of 0.2 to 0.4% for crude fiber content of the edible portion of cherries.⁹⁻¹¹ Harding¹⁰ shows the crude fiber content to be only 0.2% for cherries but he does not specify the species.

Thus, the cherry seems to rate extremely low among fruits in respect to starch and fiber contents, especially in mature fruits.

3. Acidity

Table 12 shows a progressive increase in active acidity from the time the youngest fruits were obtainable until the cherries had reached full size. The hydron concentrations of the juices of the very young fruits were similar for all varieties, ranging from pH 4.79 to 4.31 (the maximum and minimum are for varieties not listed in Table 13). A very rapid rise in active acidity occurred during the period when the fruits were making the most rapid percentage increase in weight. Most of the varieties studied attained a maximum hydron concentration about the time the chlorophyll disappeared and the fruits began to redden. The fruits then usually decreased in active acidity until they were fully ripe.

Caldwell¹ states that in all cases there was a progressive increase in titratable acidity up to full redness, after which it usually declined somewhat as the fruit became overripe. Other studies of acidity changes in cherry fruits prior to harvest show less pronounced changes for comparable periods of development.

A reduction in acidity of sweet cherries as maturity approaches,

based on both total acidity and hydrogen-ion concentration, was noted in Oregon. Data for Napoleon show that total acidity decreased from 0.897% for the juice from fruit picked June 4 to 0.620% on June 16, and then increased to 0.712% during the final nine days that the fruits remained on the trees (Figure 25). Hydrogen-ion concentration

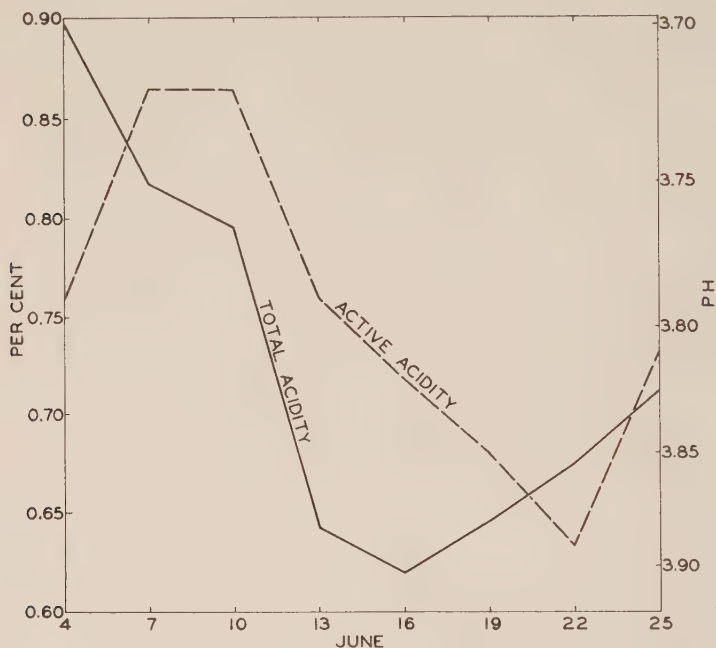


Figure 25. Total acidity, calculated as malic acid, and active acidity in the raw juice of Napoleon cherries during the ripening period.²

changed from a pH value of 3.72 to 3.89 in 15 days and then active acidity increased slightly during the final three days. The lowest acidity was recorded at the time the fruit first reached prime condition. As the fruit became ripe or overripe a slight increase in both total acidity and active acidity was noted. The total acidity of Napoleon juice was generally 25 to 30% greater than that for Bing or Lambert at any comparable stage of maturity.²

Table 13 shows a slight increase in percentage of acid as citric acid between June 11 and June 20 for Napoleon, and this is followed by a small decrease during the final 22 days prior to maturity. This

table also shows a gradual, but rather small, increase in pH values during the 31 days.

Very little change in the acidity of Montmorency juice occurred during the last three weeks that the fruits were on the trees in Wisconsin. The changes in pH for each of three years were as follows: 1932, 3.3 to 3.6 in 22 days; 1933, 3.2 to 3.4 in 20 days; and 1934, 3.2 to 3.4 in 18 days. The changes in percentages for malic acid for the same periods were: 1.63 to 1.34; 1.67 to 1.28; and 1.46 to 1.39, respectively.⁵

Windsor and Montmorency showed decreases of 10% and 9%, respectively, in total acids during the seven days preceding optimum maturity in Ontario. No change occurred in the acid content of Victor during this period.¹⁵

Kinds of Acids in Fruits. Investigators seem to agree that acidity in cherry fruits is due mainly to the malic acid content. Bigelow and Dunbar²³ show that 70 to 100% of the total acid content of the eight varieties listed is malic acid. They state that such acids as citric, tartaric, and succinic, if present, as reported by some authors, occur only in traces.

Bridges¹¹ reports the acid content of cherries (variety not specified) as follows: malic, 0.56 to 1.99%; citric, 0 to 0.01%; succinic, 0.07%; lactic, 0.13%; oxalic, trace. Kohman²⁴ lists the oxalic acid content of red cherries at 1.1 mg. per 100 g. (0.0011%) but he reports that Bing fruits contain none. Other acids that have been reported as occurring in cherry fruits are: phosphoric in some Austrian cherries;¹⁹ traces of formic, acetic and tannic in red cherries, and traces of salicylic in sweet cherries.²⁰ Current investigators, however, make no mention of these acids and their presence is to be considered questionable. Cherries may contain small amounts of volatile acids; 0.10% was found in Black Tartarian juice,⁹ and 0.0012% in an unnamed variety.²⁵

The above data, although meager, seem to indicate that acids other than malic are present in such minute quantities as to justify the general assumption that only malic acid need be determined in most varieties to provide a satisfactory picture of total acidity.

4. Alkalinity

The degrees of alkalinity (cubic centimeters of HCl required to neutralize 100 grams of ash) for cherries appears to range from 2.1 to

2.7 and that for cherry juice seems to be approximately 4.5. The lower values for the fruit are for red cherries.¹¹ It thus appears that cherries rate rather low in degree of alkalinity but that the juices are essentially as high as orange juice. Table 13 shows no consistent trends in the alkalinity numbers for Napoleon cherries during the 31 days of observation.

5. Astringent Materials

Table 12 shows that there was a gradual reduction, amounting to about 60%, in total astringent substances in Napoleon during a 48-day period of development. The non-tannic astringent substances increased slightly during the first ten days of this period and then declined rapidly from 0.358% to 0.108%. The tannin content decreased from 0.158% to 0.075% during the 48 days. Approximately 32% of the astringent substances was tannin at the beginning of the period of observation and about 41% was tannic at the time the fruits were fully ripe.

Astringent substances were much greater in Montmorency than in Napoleon and the rate of decrease as the fruits approach maturity was less consistent (Table 12). The total astringent substances for Montmorency at full ripeness were 0.438% and 0.393% for the two seasons. In 1928, 57% of the total astringent substances were tannins, and the tannin content at maturity was 0.251%, which was more than three times the percentage found in Napoleon. The decrease in tannin content in 1928 was about 49% in 32 days.

Changes in tannin content during fruit development have been shown to be closely associated with changes in astringency that are detectable to taste. There is an indication that a tannin content of less than 0.1 g. per 100 c.c. of juice does not impart detectable astringency to cherry juice. This condition was reached about the middle of a 40-day period that ended when Napoleon had attained an overripe condition. Improvement in quality is in large measure due to loss of astringency.²

6. Fats and Waxes

Cherries rank just below median among the more important fruits in fat content. The fat content of the edible portions of both sweet and red cherries ranges from 0.5%⁹ to 0.8%.¹⁰

The skins of the Bing variety gave a petroleum ether extract yield of 0.8% and an ethyl ether extract yield of 0.1% based on the weight of the dried skins. The petroleum ether extract yielded: solid fatty acids consisting of a ternary mixture of palmitic, stearic, and a small amount of acid higher than C_{18} ; such liquid fatty acids as linoleic and oleic; a small amount of glycerol; and a paraffin hydrocarbon fraction consisting mostly of nonacosane, admixed with a hydrocarbon of longer chain length. The ether extract yielded D-glucosidylsitosterol and ursolic acid.²⁶

7. Nitrogen and Protein

Table 13 shows essentially straight-line trends for increases in nitrogen during a period that begins nine days before attaining the usual degree of maturity for canning and extends three weeks beyond this stage of maturity. No explanation is offered for the fact that cherries harvested from the inner portions of the tree, and that are less advanced in maturity, show consistently higher percentages of nitrogen. The two series of samples contain similar amounts of nitrogen in milligrams per fruit. This is noteworthy since the fruits harvested from the inner portions of the tree are lower in both percentages and absolute amounts of all other constituents listed.

In contrast to the above is another report showing that both early and late ripening cherries show a decrease in total nitrogen as the fruits approach maturity. It is contended that non-protein nitrogen remains unchanged during the ripening period and that the decrease in total nitrogen is due to a decrease in protein nitrogen.²²

The amount of protein ($N \times 6.25$) in ripe fruits as reported from a number of determinations follows: 1.3 and 1.1%, respectively, for the edible portions of red and sweet cherries;⁹ mature cherries, 1.0% by weight;¹⁰ California sweet cherries, 1.14 to 1.73%, Oregon sweet cherries, 0.70 to 1.20%; sweet cherries grown in Germany, 0.46 to 0.83 g. per 100 c.c. of juice; and red cherries, 0.33 to 0.75 g. of protein per 100 c.c. of juice.²⁰

These data for nitrogen and protein contents of cherries do not appear to be consistent in trends during the period of ripening nor for analyses of mature cherries. Inconsistencies in data for mature fruits may be due to one or more of several factors, such as: variety, degree of maturity at the time of harvest, environmental factors, or

possibly to methods employed in analyses or in expression of the results.

8. Mineral Constituents

Table 13 shows that Napoleon cherries produced on the exposed portions of a tree increased approximately 28% in ash content during a 41-day period while those produced on the inner portions of the trees increased about 21% during the same period. Trends for cherries produced in the two locations of the tree are essentially straight lines that continue well beyond harvest maturity. The ash contents of cherries that may be considered sufficiently mature for canning range from 0.50% to 0.62%.

The ash content, for presumably a sweet variety, increased during a 35-day period in Europe from 0.48% on May 15 to 0.65% on May 28, remained rather constant for the next two weeks, and then increased again to a maximum of 0.74% on June 29. Nine samples of red cherries grown in Europe ranged in total ash content from 0.38 to 0.57% and 20 samples of sweet cherries to range from 0.38 to 0.62%.²⁰

Other reports on the ash content for cherries follow: red cherry average, about 0.565% ;¹⁹ sweet and red cherries at 0.6% and 0.51%, respectively,⁹ and red and sweet cherries grown in Europe, 0.38 to 0.57% and 0.38 to 0.62%, respectively.²⁰ The pits of both sweet and red cherries are reported to contain 0.6% of ash.⁹

Since the above data are for a number of varieties that may have been harvested at varying stages of maturity, it appears that sweet and red varieties do not vary greatly in total ash content. Furthermore, the data indicate that cherries are more or less intermediate among the commonly grown fruits in respect to total ash constituents.

Potassium. The cherry ranks more or less intermediate among the common tree fruits in potash content. Available reports indicate that more than one-half of the ash of both the sweet and the red cherry is K_2O .^{19,20,27} Colby²⁸ states that 1,000 pounds of fresh, sweet cherries contain 2.27 pounds of potassium.

Phosphorus. The phosphorus in 1,000 pounds of sweet cherries amounts to 0.31 pounds, which amount is exceeded only by the peach among the eight fruits studied.²⁸ The P_2O_5 content of the ash for the sweet cherry ranges from 15 to 20% by Winton and Winton²⁰ and

at 31 mg. per 100 g. for the edible portion of the fresh fruit.¹¹ Wehmer¹⁹ indicates that the average P_2O_5 content of the ash of the red cherry is 16%.

Calcium. Colby²⁸ found 0.20 pound of lime in 1,000 pounds of sweet cherries. Table 15 shows that 4.20% and 6.46% of CaO has been

TABLE 15. ANALYSES OF THE ASH OF SWEET CHERRIES, IN PERCENT²⁰

Ash constituent	Keim ^a	Colby ^b
K ₂ O	54.98	57.67
Na ₂ O	1.66	6.80
CaO	6.46	4.20
MgO	5.77	5.49
Fe ₂ O ₃	2.05	1.12
Al ₂ O ₃	1.01	—
Mn ₂ O ₃	—	0.82
P ₂ O ₅	19.85	15.11
SO ₃	3.96	5.83
SiO ₂	2.29	1.13
Cl	1.53	1.83

^a W. Keim, *Z. Anal. Chem.* 30: 401 (1891).

^b G. E. Colby, *California Agr. Expt. Sta. Rept.* 1894-1895: 177.

found in the ash of the sweet cherry by California and European investigators. Other investigators report that the Bing sweet cherry contains 19 mg. (0.0019%) and a red variety contains 10 mg. (0.0010%) per 100 g. of edible portion of fresh fruit.²⁹

Magnesium. Table 15 shows that MgO is an important constituent of the ash of the sweet cherry. Lindow *et al.*³⁰ gave the average for fresh fruits at about 1.0 mg. per kg. but found that the red cherry yielded 1.4 mg. per kg. of fresh fruit.

Sodium. The two sets of ash analyses shown in Table 15 are in substantial agreement for all ash constituents except Na₂O. Which of the two percentages for Na₂O would be most closely approximated by analyses of the present leading varieties is questionable.

Sulfur. Shedd³¹ found two to eight times as much sulfur in 1,000 pounds of cherries as was found in other fruits analyzed (1.08 pounds per 1,000 pounds). Bridges¹¹ reports the sulfur content as 6.8 mg. per 100 g. of edible portion of fresh fruit. Table 15 shows 3.96% and 5.83% SO₃, respectively, in the ash of European and California sweet cherries.

Iron. Keim found substantially more Fe_2O_3 in the ash of the sweet cherry than did Colby (Table 15). The amounts of iron found by other investigators are: black sweet cherry, 5.1 mg. per kg., and red cherry, 4.6 mg. per kg., fresh weight basis;²⁷ black sweet cherry, 0.80 mg. per 100 g., red sweet cherry; 0.40 mg. per 100 g., and red cherry, 10.0 mg. per 100 g. of edible portion;²⁹ sweet cherry, 31 mg. per 100 g. of edible portion;¹¹ black sweet cherry, 0.00051%; and red cherry, 0.00046%.³²

Chlorine. Table 15 shows that chlorine accounts for 1.53 to 1.83% of the ash content of sweet cherries. Bridges¹¹ reports 14 mg. of chlorine per 100 g. of edible portion of sweet cherry, or 23 mg. of chlorine as sodium chloride.

Silicon. Table 15 lists 2.29% and 1.13%, respectively, of SiO_3 in the ash of sweet cherries grown in Europe and in California.

Manganese. Table 15 shows that one investigator found 0.82% Mn_2O_3 in the ash of the sweet cherry. Lindow and Peterson³³ found the manganese content of fresh cherries to be 2.5 mg. per kg., while the average for fresh material of all fruits studied was 4.0 mg. per kg.

Aluminum. The Al_2O_3 content of the ash of the sweet cherry was found to be 1.01% for fruits grown in Europe (Table 15). Other analyses show 34.9 mg. of aluminum per kg. of stored fruit and 70 mg. per kg. of fresh fruit.²⁰

Copper. Three reports give the copper content of fresh cherries as 1.4 mg. per kg.^{11,27,30} Other analyses show 1.6 mg. per kg. on a fresh basis and 15.6 mg. per kg. on a dry basis.²⁰

Iodine. One report indicates that the cherry contains no iodine but another report indicates 3.3 mg. per 100 g., dry basis.^{20,29}

Bromine. Bridges¹¹ claims that dry cherries contain 33 p.p.m. bromine.

Zinc. One investigator found that the edible portion of fresh, red cherries contains 1.5 mg. of zinc per kg.²⁰

9. Color Development

The red color of cherries is due to an anthocyanin which is confined largely in the outer epidermis.³⁴ The coloring material in brownish-yellow sweet cherries is a glucoside called fuscophobaphen ($\text{C}_{27}\text{H}_{26}\text{O}_{12}$). Red sweet cherries have a glucoside designated as rubrophlobaphen with a possible formula of $\text{C}_{35}\text{H}_{34}\text{O}_{17}$. The red

glucoside in red cherries is thought to have a formula of $C_{37}H_{50}O_{25}$.¹⁹

Reddening in the cherry seems to depend on temperature while light apparently has no direct action on this phenomenon.³⁵ The kind of spraying material applied to the trees seems to affect the development of color pigment. Red cherries produced on trees sprayed with lime-sulfur were light in color, while those sprayed with proprietary copper compounds varied from light to dark red and those sprayed with Bordeaux varied from light red to very dark red.³⁶ Certain organic spraying materials also tend to produce cherries that are light in color.⁶

10. Flavoring Materials

The characteristic flavor of cherries is due mainly to a benzaldehyde.³⁷ A liter of Montmorency juice was found to contain 2.8 mg. of a benzaldehyde and a trace of alcohol having a rose-like odor, possibly geraniol, that also may contribute to the flavor.²⁵ The benzaldehyde found in the cherry aids in eliciting a pleasing flavor.³⁷

11. Enzymes

Investigators have not found oxidase in black sweet cherries and peroxidase is found only in unripe fruits. Invertase and amylase are present in the pulp and emulsin is present in the seed at all stages of development.²⁰ Neither amygdalin nor phlorizin is present in the skin of the cherry.¹⁹

12. Vitamins

Of the 14 vitamins, or groups of vitamins, whose chemical characteristics and specific functions are known, only five have been mentioned as occurring in the cherry fruits. Vitamin assays for cherries have been made by only a few investigators, hence the amount of available data is meagre compared with that available for a number of other fruits. Furthermore, a number of the investigators have not specified either the variety or the species with which they worked and no one seems to have attempted to determine trends in vitamin content during the ripening period.

Vitamin A. Recent work in British Columbia gives a range of

46 to 90 and an average of 62 mg. of carotene per 100 g. of fresh edible portion of sweet cherries and no significant varietal differences. The investigators state that some higher values reported may have included red cherries.¹⁴ The cherry is rated as good in vitamin A potency.^{10,11,38} One report shows 145 I.U. per 100 g. of fruit,³⁹ and another gives a range of 15 to 150 I.U. for cherries, indicating substantial variation among varieties.¹¹ The carotene content amounts to 0.42 mg. per 100 g., according to a recent report.²⁹

Potter and Dickson³⁸ state that 0.25 to 0.375 g. of such varieties as Montmorency, Late Duke, and Napoleon provide one I.U. of vitamin A potency. Approximately 0.375 g. of Bing and 0.375 g., or more, of Lambert and Deacon are required to provide the same potency. They conclude that the red and hybrid varieties of cherries are more potent than the black sweet varieties.

Thiamine (Vitamin B₁). Harding¹⁰ says that the cherry contains a fair amount of thiamine but work done in South America indicates only a trace of thiamine.³⁹ Two assays show 0.048 and 0.051 mg. of thiamine per 100 g. of edible portion of fruit.^{29,40} Varieties are not specified in any of these reports.

Riboflavin (Vitamin B₂). One report gives the riboflavin content of the cherry as 65 γ per 100 g.³⁹ This is the equivalent of 13 I.U. In comparison with other fruits, the cherry is one of the best sources of riboflavin.

Niacin. The niacin content of cherries is generally rated at 0.127 to 0.145 mg. per 100 g.²⁹ but a content of 0.550 mg. per 100 g. was observed in South America.³⁹ The former range of values are similar to those for apples and the citrus fruits but are substantially lower than the niacin contents of other stone fruits.

Ascorbic Acid (Vitamin C). The ascorbic acid content of the cherry and the peach is higher than that of other deciduous tree fruits, but is only 12 to 25% of that found in citrus fruits. Some of the reported values for ascorbic acid content of cherries are: 8.0, 9.0, 10.0, and 10.6 mg. per 100 g.^{11,29,39,40} The Napoleon variety, however, seems to be notably low in ascorbic acid content; one report says it contains only 2.1 mg. of ascorbic acid per 100 g.¹¹ while Charley, working in England, found only a trace, which he states is a confirmation of determinations made by other workers.⁴¹ Bing and Lambert ranged from 1.1 to 11.6 and 3.7 to 24.8 mg. per 100 g., respectively, in British Columbia while Van ranged from 3.7 to 24.8.¹⁴

Other Vitamins. The absence of reported values for vitamins other than those just provided does not mean that all others are lacking in cherries. Comparatively few vitamin assays have been made for the cherry and it is likely that the investigators have been concerned principally with the more important vitamins.

13. Nutritive Value

The cherry apparently has a caloric value somewhat higher than the average for the commonly cultivated fruits. Morgan⁴⁰ ranks it third in caloric value among 11 of the more important fresh fruits. She bases the values on 100 g. of fruit "as purchased." However, if the values are based on average servings, and 12 sweet cherries are considered an average, the sweet cherry ranks lower in caloric value than any of 14 other tree and small fruits.²⁹

Some of the caloric values reported for cherries are as follows: 63 per 100 g. of edible portion of red cherry and 80 per 100 g. of edible portion of sweet cherry;⁹ 78 per 100 g.;¹⁰ 64 per 100 g. of cherries as purchased;⁴⁰ 40 for 12 sweet cherries.²⁹

Caloric values do not provide a complete picture of nutritive values. Along with them, consideration should be given to vitamin content and mineral content. Morgan⁴⁰ has calculated "significant nutritive indices" for a number of fruits, indicating the percentages of over-all nutritive requirements for one day that may be supplied by 100 g. of a fruit as purchased. The index for the cherry is 5, which is higher than that for the apple, the plum, the grape, the pear, and the banana, but substantially lower than the index value of 20 given to the apricot. Also the red cherry ranked fourth in calculated relative and nutritive-unit cost values for usable portions of 20 fruits. Which means that it supplies calories, vitamins, and minerals at low cost per serving unit.¹²

14. Post-Harvest Changes

It is generally thought that no appreciable physiological or chemical changes occur in the cherry after it is harvested. Hartman and Bullis² found no increase in sweetness, no improvement in quality, and no other change occurring after sweet cherries were removed from the tree, even at high holding temperatures, other than volume and

weight losses due to some dehydration. They conclude that cherries develop quality only when attached to the tree. Their conclusions are in substantial agreement with the observations of many pomologists and growers.

In contrast to the above determinations and observations are the recent reports of Efimenko⁴² and Upshall and van Haarlem.¹⁵ The former found that monosaccharides increase during storage as a result of splitting of sucrose and of polysaccharides. He states that total sugar increased 3.34% during ten days subsequent to harvest and that actual acidity decreased.

The following changes are reported for fruits of the Victor, Windsor, and Montmorency varieties held at room temperature for one week after harvesting at different stages of maturity: a slight increase in intensity of red color occurred; sugar increases of small proportions took place; the total acid content of Windsor and Montmorency decreased; a marked increase in yield of juice occurred after seven days of ripening, but there was no appreciable change in quality during the holding period.¹⁵ Apparently, this is a preliminary report and it does not show the data for the changes in acidity and sugar that are reported to have occurred subsequent to harvest.

A remarkable case is also cited where the aluminum content decreased from 70 mg. per kg. to 34.9 mg per kg. during storage.²⁰

Allen⁴ states that cherries do not actually gain in soluble solids and sugars after removal from the tree. If, however, the fruit is held in a dry atmosphere, some dehydration will cause the cherries to show a higher percentage of soluble solids than when harvested. He points out that cherries may become sweeter and more palatable to the taste after removal from the tree, but that this change is due to a loss of acid and tannin rather than to any increase in solids and sugars. Thus, he states, the opportunity to improve dessert quality after removal from the tree is limited.

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FRUIT MATURITY AND FRUIT HANDLING

The amount of crop per tree or per acre and the quality of the cherries may be influenced appreciably by the stage of maturity attained when the fruits are harvested. Hence, the determination of the proper stage of maturity for harvesting for the various forms of utilization is of great importance in determining profits and in maintaining favorable consumer acceptance for both fresh and processed cherries.

It is not easy to determine when a variety of cherries has reached a stage of maturity that will provide the greatest net income to the grower, and, at the same time, provide a maximum of quality for the consumer. However, it is seldom possible, and often not advisable, to harvest all of the crop at optimum maturity. Harvesting operations for a variety of cherries cannot be completed in a day, and often not even within two weeks. Moreover, it is sometimes advisable to harvest certain early varieties of sweet cherries, that are to be transported long distances, before they are fully mature in order to take advantage of a high-priced market. Consequently, indices for the determination of degree of maturity should be employed as guides in aiding the grower to know when harvesting operations should be initiated in order to pick most of the crop at a time that will give high financial returns and still provide the consumer with a quality product that will mean repeated sales.

1. Indices of Maturity

The reputation of the sweet cherry has suffered because some of the fruit has been harvested at the wrong time. Much of the product on the fresh fruit markets has been flat because the cherries were harvested too early. Harvesting too early results in loss of tonnage, but allowing the cherries to become overripe also results in loss of

weight and volume. Much of the premature harvesting of sweet cherries is due to fear that the fruits will crack if allowed to mature fully.¹

A. SIZE OF FRUIT

Size of fruit is not an index of maturity for cherries. When cherries ripen during hot and dry weather, they may attain full maturity when they are relatively small, but when comparatively cool and humid weather prevails during the ripening period the fruits may attain large size before they are fully ripened. Also, trees carrying heavy crops usually produce fully matured fruits of smaller than normal size. Furthermore, cherries that vary substantially in size, yet having the same degree of maturity, may be harvested at one time from the same tree.

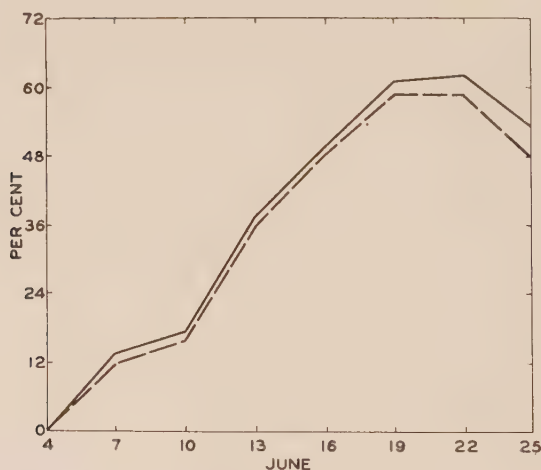


Figure 26. Correlation between percentage increase in weight (solid line) and percentage increase in volume (broken line) for Napoleon cherries.¹

Correlation of Weight and Volume. Size of fruit is directly correlated with yield. Maximum size of fruit is therefore one of the requisites for maximum yield of commercial fruit. An increase of 10% in size of fruit means approximately 10% increase in tonnage. Such increases may occur in one week under favorable conditions for ripening, and they may be sufficient to offset a substantial portion of the heavy expense incurred for harvesting the crop.

Size of fruits may be determined by either measuring the dis-

placement when fruits are immersed in water or by weighing the fruits. Figure 26 shows a very close relationship for percentage increase in volume and weight. Some investigators have used the water displacement method¹⁻³ and some have employed weighings to indicate growth rates of the fruit.^{1,3-7} Apparently, either method will provide an equally satisfactory measure of growth rate.

Rate of Increase in Size. It was shown in Chapter IV that the cherry passes through three distinct stages of growth and development between the time of fertilization of the ovule and the attainment of full

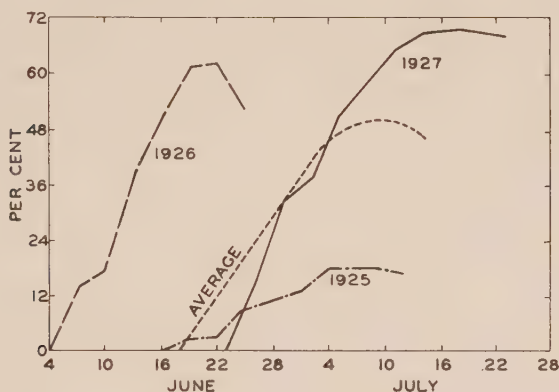


Figure 27. The influence of season on percentage increase in weight of Napoleon cherries during the ripening period. The fruits continue to gain weight until they are fully ripe, but hot weather, such as prevailed during the ripening period of 1925, reduces growth rate and results in early termination of growth.¹

maturity of the fruit and that most of the enlargement of the pericarp of red cherries takes place during the two to four weeks preceding full ripeness. The fruits continued to increase rapidly in size for three to nine days after reaching full ripeness and then ceased growth, or even declined slightly in size.

The Napoleon cherries included in Table 12 increased in size most rapidly between May 28, when they were whitening, and June 5, when they had become red. These fruits had attained a canning ripe condition on June 18, but continued to increase in weight at a rate of approximately 1.5% per day until they were fully ripe on June 22. The increase in size for the Montmorency preceding ripening is even

more striking. Between the time that they were white (June 5) and full red (June 18), the weight increase amounted to 188%. The gain in weight during the final four days between a full red condition and canning ripe amounted to 0.89 g. per fruit, or more than 25% of the final weight.

The growth rates for Napoleon fruits during the ripening periods of three successive seasons are expressed in terms of percentage increases in weight in Figure 27. A great deal of the increase in size of fruits occurred early in the ripening period but the fruits continued to gain in weight until they were fully ripened. After reaching full maturity, the fruits showed some decrease in weight, which was due to loss of moisture. This is well illustrated by the broken line of Figure 27 which shows the average growth rate for a 26-day period for the three seasons. The average rate of increase in weight per day for the first two weeks of this period was approximately three percent per day. The rate of size increase then declined for approximately one week and finally the fruits decreased slightly in size. These cherries were designated as being ripe on the following dates: 1925, July 1 to 4; 1926, June 19 to 22, and 1927, July 13 to 16. The dates of full ripeness correspond rather closely to the peak portions of each of the curves. Hence, the cherries were either very ripe or over-ripe when they began to decrease in size.¹

Figure 27 indicates that temperature during the ripening period influenced the rate of growth and the ultimate size attained by sweet cherries in Oregon. Hot weather during ripening in 1925 limited size increase during an 18-day period to 18.3%. Long periods of cool weather prevailing in both 1926 and 1927 permitted the fruits to gain 62.5 and 70.0%, respectively, in weights in three weeks or less time. Thus, comparatively cool weather favored continued growth at a relatively high rate, but a few days of hot weather seemed to result in quick ripening and termination of growth of fruits. No information is provided by the authors to indicate the availability of soil moisture during these years.

Bohart⁶ found that Napoleon cherries gained 14.5% in weight in nine days, or an average of 1.6% per day, prior to reaching the usual stage of maturity for canning. During this period they had changed from a slight blush to 50% blush. In the 22 days that followed, they gained only 3.8% in weight. A 37% increase in weight in 15 days preceding optimum maturity for Bing and Lambert, or an average of

nearly 2.5% per day occurred in British Columbia.⁴ During this 15-day period these varieties changed from light red to dark red. Data obtained in Washington show gains of 19 and 23%, respectively, for Bing and Napoleon in 12 days prior to the time of canning.⁵ This report states that despite the higher unit price paid for cherries for

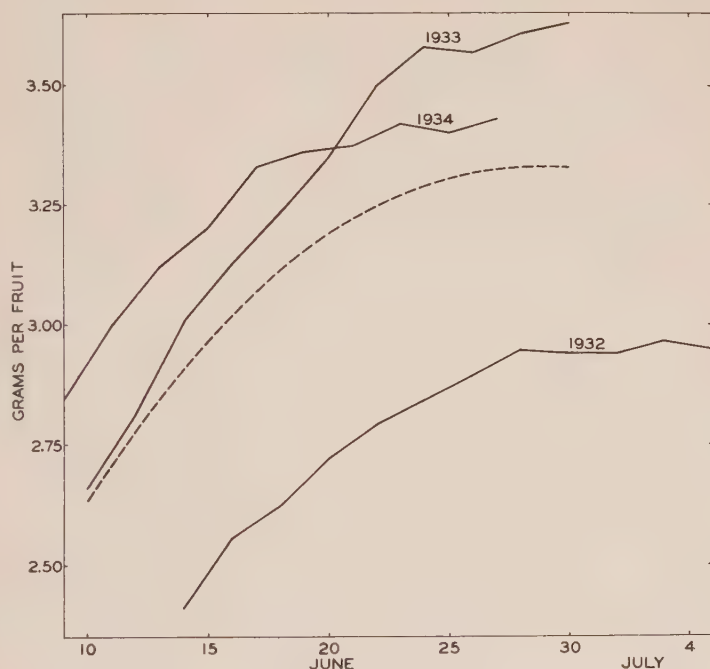


Figure 28. The influence of season on the increase in weight of Montmorency cherries during the ripening period. The broken line shows the approximate average growth curve for the fruits, based on data for the three seasons. (From data of Kiett *et al.*⁶)

early shipping, greater yield and improved grade of canning-ripe cherries more than compensated for the price differential. The following increases in size of fruit in seven days were recorded in Ontario: Victor, 8% ; Windsor, 10% ; and Montmorency, 11%.⁷

Further information on size increase during the ripening period is presented for the Montmorency variety in Figure 28. One of the three seasons for which records are available was unfavorable for size

increase. The average rate of increase in weight during the first seven days is 2.2% per day. The rate decreases to an average of 1.0% per day during the second week and after the cherries reach full maturity the rate declines to an average of about 0.2% per day.

Substantial increase in size is one of the outstanding characteristics of maturing cherries. In general, it appears that cherries may be expected to increase in size at a rate of two to three percent per day during the period preceding the week prior to full ripeness and that the rate of increase in size during the week prior to optimum maturity may be about one to two percent per day, providing that reasonably cool and humid weather prevails. The attainment of maximum size seems to be associated closely with optimum maturity. A slight decrease in size may result in unharvested cherries after the attainment of optimum maturity. Thus, while size of fruit is not an index of maturity, it appears that rate of increase in size may be used to indicate maturity. In other words, when the daily rate of increase in size of fruit in a normal season becomes less than, say, 0.5%, the fruits probably have reached optimum maturity for canning. In many commercial orchards, however, harvesting operations must start several days in advance to permit harvesting large acreages of one variety before the cherries become over-ripe.

B. COLOR OF FRUIT

Two fundamentally different types of color must be given consideration in maturity studies. The young fruits show only a chlorophyll green color which turns to lighter shades as the fruit develops. This is known as the basic color, ground color, or under-color. The red coloring which develops as the fruits approach maturity is generally designated as the over-color or simply as the red color.

Ground Color. The varieties of sweet cherries that do not become completely red or those that have only red blushes at full maturity are generally designated as light-colored ones. Typical examples of such varieties are the Napoleon, Victor, and Yellow Spanish. The former variety may have 50 to 75% of the surface of the fruit showing shades of light red coloring matter and the balance of the surface showing ground color when fully ripe. The ground color changes gradually during the ripening period from green to pale yellow, and, finally, to light gold at full ripeness.

The change from green to the yellow shades is independent of

sunlight and the change is definitely correlated with development of maturity.¹ Thus, the ground color changes in the cherry are very similar to those that occur in other deciduous tree fruits, but no one seems to have developed a ground color chart for this variety such as is used for determination of maturity of apples and pears.

Similar ground color changes probably occur in the fruits of the dark-colored sweet cherries and in the red cherries, but they are masked by an early development of anthocyanin pigments.

Red Color. The term "red color" may not be a proper designation for the over-color, since some of the varieties of sweet cherries become purplish-black or even black when fully ripened.

In the light-colored varieties of sweet cherries, both the percentage of surface showing red coloration and the intensity of the red coloring matter increase as the fruits ripen. Hartman and Bullis¹ state that the red color gains in intensity until about mid-season and then shows no further change, but other investigations show that Napoleon fruits changed from 50% of surface blush to 80% in the three weeks following the time of initial harvesting for canning, and that the amount of surface blush on Victor changed from 66% to 82% during the week preceding optimum maturity.^{6,7}

The development of red color in the light-colored varieties of sweet cherries is affected by sunlight, but intensity of red color is not an index of degree of maturity of such cherries.¹

The dark-colored varieties of sweet cherries, such as Bing, Lambert, and Republican, change from a light red through reddish-purple to a deep purple, or even black, color while the red cherries change from a light cherry-red to dark red or reddish-mahogany during the ripening period. These changes definitely are associated with maturity. Cherry growers know this since they rely mostly on color intensity and flavor as indices to maturity. The California State Department of Agriculture uses a red color chart as an indication of the minimum acceptable maturity for dark sweet cherries.

Bing and Lambert are reported to have attained optimum maturity in British Columbia when dark red⁴ but in Oregon these varieties were dark purple or even black when they were considered fully ripe.¹ Ridgeway's color standards were employed in Ontario in an attempt to measure the color change qualitatively. Windsor changed from Nos. 822 to 1028 to No. 1030 in one week, while Montmorency changed from No. 822 to No. 824 to 826 in the week prior to attainment of optimum maturity.⁷

The dark sweet cherries and the red cherries are unlike many deciduous tree fruits in that red color develops independent of sunlight. Specimens of dark-colored cherries growing in the shade of leaves and those that were covered developed almost as much color as those exposed to sunlight.¹ Red cherries also seem to develop as much color in the shade as when exposed to direct sunlight. However, cherries growing in shaded portions of the tree are often later in reaching a stated degree of maturity than those growing in more exposed locations.⁶ Thus, one of the reasons that intensity of color development in the dark sweet cherries and the red varieties may be employed as an aid in determining the degree of maturity is that color development is independent of sunlight.

The California standards for maturity are based on the assumption that all dark varieties of sweet cherries that have attained a solid light-red color are mature and that they will continue to full color development and acceptable dessert quality during transit to eastern markets. However, this assumption is supported only in part. During the shipping season of 1941, only 73% of 100 representative samples of Black Tartarian and 49% of 72 samples of Bing that had attained such a degree of color development were actually mature in the sense that they would develop satisfactory color and dessert quality after a storage period of 10 days at 42°F. Chapman, Burbank, Black Tartarian, and some Bing samples that had attained solid, medium-red color did ripen normally.⁹

The juice of light-colored varieties of sweet cherries and of red varieties such as the Montmorency does not change color during the ripening period, but juice of the dark-colored sweet varieties and of a red variety like English Morello changes to shades of purple. The change is gradual and of questionable value as an index of maturity.

C. FIRMNESS OF FRUIT

Special pressure testers have been devised to determine the rate of softening of cherries as they approach maturity, but the rate of softening is so slow and of such small magnitude that the use of pressure testers does not appear to be feasible. One such device used a glass plunger with a rounded point that was 2 mm. in diameter and measured the amount of pressure required to make a specific indentation on a Chatillon metric scale. The decrease in readings with this pressure tester for Napoleon amounted to only 17.3% from imma-

turity to prime condition. Furthermore, the decrease in pressure-test readings within the marketable picking season amounted to only five percent. The rate of decrease was not as uniform as would be desirable for such a low range of readings.^{1,10}

A special squeeze pressure tester to test the rate of softening of cherries gave readings of 3.9 lb. one week prior to optimum maturity for Windsor and 3.4 lb. at optimum ripeness. The Montmorency variety showed a decrease from 1.7 lb. to 1.4 lb. during a similar period. No significant changes in pressure test readings occurred after harvest. It was concluded that the pressure test is not practical as a means of measuring the degree of maturity of cherries.⁷

D. DAYS FROM FULL BLOOM TO MATURITY

The number of days elapsing between full bloom and ripening in New York are shown in Table 16. The maximum seasonal differences of elapsed time between bloom and maturity are greater for cherries than those reported in the same paper for other fruits. This

TABLE 16. ELAPSED INTERVALS, IN DAYS, BETWEEN FULL BLOOM AND FRUIT RIPENING, AND MAXIMUM SEASONAL DIFFERENCES, IN DAYS, FOR SOME VARIETIES OF CHERRIES IN NEW YORK¹¹

Variety	No. of seasons	Length of season			Maximum seasonal elapsed differences from bloom to maturity
		Shortest	Longest	Average	
Sweet varieties					
Bing	5	60	74	71	14
Black Tartarian	7	49	63	57	14
Governor Wood	9	43	50	47	7
Knight	12	44	55	51	11
Lambert	7	61	72	69	11
Napoleon	6	67	74	68	7
Rockport	8	42	56	52	14
Schmidt	0	62	74	72	12
Windsor	6	65	76	75	11
Yellow Spanish	6	60	70	67	10
Red varieties					
Early Richmond	17	47	57	50	10
English Morello	29	60	74	70	14
Montmorency	14	54	64	62	10
Duke varieties					
Late Duke	5	60	72	66	12
May Duke	9	41	55	51	14

makes possible a rather large error in predicting time of optimum maturity on the basis of date of full bloom. However, it would appear that the time of optimum maturity for most varieties of cherries can be predicted within five to seven days.

The rather high degree of variability in elapsed time from full bloom to optimum maturity in the red cherry seems to be due to effects of growing season temperatures and size of crops borne by the trees. Low growing season temperatures retard ripening greatly and high temperatures accelerate ripening in the Montmorency. Trees with light crops mature their fruits early and evenly and those with heavy crops tend to be later and more uneven in maturing their crops. The highest yielding trees may ripen their crops an average of four days later than those carrying moderate crops.¹² Similar observations are reported for sweet cherries.¹³

The application of nitrogenous fertilizers also may delay maturity of cherries. Such effects have been noted with sweet cherries in California¹³ and it has been observed in Michigan that trees of the Montmorency variety that have been fertilized heavily with nitrogen were four or five days later in attaining optimum maturity for canning than trees fertilized moderately in the same orchard.

The evidence seems to indicate that a number of factors have greater relative effect with cherries and thus make this means of predicting maturity less reliable than is the case with apples, pears, and peaches.

E. SOLUBLE SOLIDS CONTENT

The soluble solids content of the expressed juice of cherries is regarded generally as a reliable index of maturity. However, there is not complete agreement among investigators on this point. In an investigation that involved more than 800 samples from commercial orchards in Northern California, it was found that the soluble solids content of the four varieties studied was more variable than degree of red color development. Soluble solids were found to vary with year of production, with the district in which the cherries are produced, and with the size of the crop produced by the trees. Color is regarded a more reliable index of maturity for red varieties of sweet cherries than is soluble solids in California.¹⁴

Investigators that regard soluble solids content as the most reliable index of maturity are not in complete agreement as to the mini-

mum Brix, Balling, or refractometer readings that varieties should attain before they are harvested for fresh fruit shipment or for processing. This may be due in part to regional differences in sugar content and in part to personal opinions as to what constitutes acceptable quality.

Hartman and Bullis¹ state that Napoleon, Bing, and Lambert have attained sufficient quality for eating in a fresh state when the Balling test reading is 20%. Republican should have 22% soluble solids and such early varieties as Black Tartarian and Governor Wood should attain a reading of 16% to provide satisfactory dessert quality. They state that the Balling test is not ideal but that it is the best index of maturity of the several tried.

Fisher and Britton⁴ found that Bing cherries possessed good dessert quality when they had developed 19% soluble solids. This recommendation is essentially the same as that of Hartman and Bullis. However, Fisher and Britton found that Lambert possessed good dessert quality when the soluble solids content reached 17%.

Other investigators have not made specific recommendations for minimum hydrometer readings. However, Britton¹⁵ says that 16% sugar content at time of harvest is too low for such varieties as Bing, Lambert, and Victor because, at this low level of sugar content, the fruits shrivel in storage, have poor flavor, and become unattractive. Further information on sugar and soluble solids content for varieties of cherries is available in the preceding chapter.

The juice for hydrometer readings should be extracted from one-half to one pound of cherries representative of all stages of ripeness and representative of the block of trees. The cherries should be ground in a food chopper fitted with one of the coarser blades. It is not necessary to remove seeds and stems. The chopped cherries are then pressed slowly through a single thickness of canvas, with a small press, until practically all of the juice is expressed. Pulp and sludge do not interfere with the readings. The juice should not be filtered. The juice is then placed in a glass cylinder and a hydrometer with a narrow range of Brix or Balling scale (15 to 30 for sweet cherries) is placed in the cylinder of juice to indicate directly the percentage of soluble solids. The reading should be made at the bottom of the meniscus and the temperature of the juice should be approximately that for which the hydrometer is standardized.

Laboratory or field refractometers (hand refractometers) may

also be used for the determination of soluble solids of the juice. Most of the larger processors of cherries have such equipment. They are generally regarded as more accurate than hydrometers. Methods for extraction of the juice should be similar to those just presented.

F. OTHER MATURITY FACTORS

Some of the softer varieties of sweet cherries that mature early should be picked at earlier stages than the firmer and later varieties because the former soften enough to become easily injured during handling and shipping operations when they are ripe. Again, the early price for the early varieties may be sufficient to more than offset the returns that would result from greater size of fully ripened fruits.

Sweet cherries that are to be held in storage should not be permitted to become over-mature before they are harvested.¹⁶ These cherries are usually picked with the stems for the fresh market and it is desirable to have the stems in a bright green condition when the cherries reach the consumer. The green color of stems of the Bing variety is preserved better with fruits that are harvested before the cherries attain a mahogany red. When harvested at a mahogany red stage, the stems are inclined to develop brownish-red discolorations that detracted from appearance.¹⁷

G. SUMMARY OF INDICES OF MATURITY

There appear to be only two reliable indices of maturity of cherries—color development and percentage of soluble solids. The ground color changes in the light-colored varieties of sweet cherries, and the intensity of red color development in the dark varieties of sweet cherries and red cherries, are closely associated with the stage of maturity, and neither kind of color change is influenced appreciably by environmental factors.

The percentage of soluble solids as indicated by the Brix or Balling hydrometer or the refractometer is correlated closely with sugar content of cherries and both are correlated with stage of maturity. Certainly, the processor is interested particularly in solids and sugar content and should employ a refractometer or a hydrometer as an aid in determining when a variety from a specific orchard should be harvested. Perhaps the best substitute for actual measurement of soluble solids content is taste or flavor since there is a close association between the attainment of acceptable flavor and high sugar content.

Size cannot be relied upon to indicate degree of maturity because cherries grow more rapidly and attain larger size in some seasons than they do in others. A retardation in rate of size increase, however, may be an indication that the fruits are nearly mature.

Change in the firmness of the fruit of cherries is of such small magnitude that this important index of maturity of some other kinds of fruit is not practical with cherries.

Finally, the elapsed time between full bloom and optimum maturity for cherry varieties is too variable from season to season to permit the employment of this factor except to indicate approximately when harvesting operations should be initiated.

2. Prevention of Losses by Birds

Birds attack cherries that are ripe or nearly ripe and may cause much damage just prior to and during harvesting operations. They peck out portions of the riper fruits, remove whole cherries, and knock some fruits to the ground with their wings. Damage by birds, however, is not a problem in arid regions where bird population is relatively low.

The relative amount of damage caused by birds in cherry trees is inversely proportional to the number of trees of a variety in an orchard and is usually much more severe with early varieties of sweet cherries than with late varieties of this species or with red cherries. In areas where cherry production is concentrated, the total number of cherries damaged may be very large but damage per tree or per acre is likely to be of little consequence.

The percentages of loss by bird damage to four varieties in a large orchard for one week prior to the attainment of full maturity in Ontario ranged from 0.5% for a variety known as Hedelfinger to 10.0% for Schmidt. However, the size increase ranged from 13.0 to 33.0% during the week, indicating that it would have been unprofitable to have picked the fruit early to avoid losses caused by birds.¹⁸

A study of damage caused by birds in commercial Montmorency orchards in Michigan showed that robins were responsible for most of the losses, but starlings also caused much damage by alighting in the tops of trees while traveling at rapid rates and pecking at the fruit in triphammer fashion. The latter also knock much fruit from the trees with their wings. Crows did not appear to cause serious losses in these orchards.¹⁹

Of the various devices tested for lessening damage by birds an automatic acetylene exploder or flash gun suspended from a cross arm mounted near the top of a tall pole and set to explode at two-minute intervals gave best results. Both the noise caused by the explosion and the motion of the exploder were factors in reducing the bird populations in the orchard. One exploder for each three acres is recommended.¹⁹

3. Fruit Handling Practices

A. HARVESTING

Harvesting is the most expensive of all operations associated with the production of cherries. Since harvesting is a hand operation, commercial cherry growers must assemble a considerable number of pickers for a comparatively short harvesting season, and must often begin picking before the fruit is fully mature to complete harvesting before the cherries become over-mature.

Sweet and Duke Cherries. Varieties of cherries that belong to the sweet and Duke groups are picked with the stems intact unless they are to be delivered to processing plants that are located within a few hours' trucking distance from the orchards or are for local fresh fruit markets in some of the eastern areas of production. Pulling the cherries from the supporting stems causes a slight wound from which fruit juice is likely to exude. This juice causes the surface of the fruits to become sticky and unattractive and it also furnishes a medium for the development of decay organisms.

The picker should grasp the stems of a cluster of fruits and give them a slight backward twist and pull. If care is used in performing this operation, the stems should remain firmly attached to the fruits and few, if any, spurs should be broken from the trees. Some growers have the pickers use shears or scissors to clip the stems at approximately their mid-points. Pickers that become accustomed to this method of harvesting object to picking in the usual manner, even though it is slower.²⁰ In general, twice as many pickers per acre are required for sweet cherries as for red cherries because the season for the former is shorter and the trees are larger, involving more ladder work.

All of the fruits produced by sweet cherry trees usually are picked at one time except in California where color is used as an index of maturity. Two, or even three, pickings may be made from the same trees in California.

Red Cherries. Most of the red cherries produced in commercial orchards are processed at factories located within 250 miles of the orchards. They are therefore picked by pulling or "stripping" the fruits from the stems, leaving the latter on the trees. This method of picking is more rapid than picking with the stems and it saves the expense of stem removal at the processing plant. Most processing plants will not accept cherries that have stems because of the time and expense involved in stemming.

Pails holding four to nine quarts are usually used for picking, though baskets and other types of containers holding five to ten pounds are sometimes used. The picking container is usually fastened to the belt of the picker with a hook or the hook may be used to hang the picking container on a limb or a rung of a ladder. A good picker operates with both hands and should be able to strip 400 pounds per day from trees that are carrying good crops. However, 200 pounds per day is about average.²⁰ Since a good yield of Montmorency cherries is three to four tons per acre and the picking season for an individual orchard will average about 15 days, it would appear that two to four pickers per acre would suffice. Actually, the number of pickers per acre varies from less than two to eight or ten for an orchard carrying a good crop, because much of the picking is done by families and some of the younger pickers are much slower than the average adult. Pickers are usually paid on a piece-work basis.

Cherries are usually transported to processing plants or receiving stations in lugs that hold 25 to 28 pounds. The lug boxes used in the Great Lakes region have inside dimensions of $5\frac{3}{4} \times 10 \times 21$ inches. These lug boxes are usually supplied to the growers by the processing plants. The grower may deliver the lugs of cherries directly to the processing plant or he may deliver to a nearby receiving station where large trucks pick up the lugs for transportation to the processing plant. Some large growers have enough volume to warrant the processor-owned or -operated trucks to call at the orchard for the cherries.

Investigations under way in Michigan indicate that it is entirely practical to transport red cherries 200 miles to processing plants in sheet metal tanks holding approximately 6,500 pounds of cherries and 1,500 pounds of water to cushion the fruit. Baffles are necessary to reduce shifting of the load in transit. Such cherries arrive at the plant in better condition than those transported in lug boxes and they undergo the "soaking" process enroute.²¹

B. SPRAY RESIDUE REMOVAL

The usual "soaking," fluming, and washing treatments to which cherries are subjected in processing plants reduces accumulated residues of lead and arsenic well below the established tolerances. Consequently, there has never been a serious problem of the usual spray residues on cherries that are processed. This, however, must not be construed as an indication that residues of DDT and other materials that are not recommended for cherries can be removed by the usual methods employed in processing plants.

Cherries that are grown for the fresh fruit markets may carry residues exceeding the current tolerances of 0.025 g. of arsenic as arsenic trioxide and 0.050 grain of lead per pound of fruit. If the lead arsenate sprays are applied only during the early part of the season, residues in excess of the tolerances are not generally encountered. Second cover sprays with this spraying material, especially in a dry season, may result in a residue that exceeds the tolerances at harvest time. Some of the cherries of both sweet and red varieties grown in the Hudson River Valley were found to carry residue in excess of current tolerances when the spray program met the minimum requirements for the control of cherry fruit flies.²² It has also been necessary to reduce the residue load in some of the western areas of production in certain seasons.²³

Equipment for Washing. Commercial fruit washing machines adapted to washing cherries have not been developed. The fruit is usually washed in dipping tanks. Two wooden tanks, each about five feet long by two feet wide by one foot deep have been recommended for use. These may be made of ordinary rough lumber, using two-inch material for the bottoms and ends and either one-inch or two-inch material for the sides. The joints should be covered with asphaltum paint and nailed or screwed together before the paint dries. One tank is used for the washing solution and the other is a rinse tank. At one end and at the top of the latter tank, a notch 2 x 2 inches should be cut to allow for an overflow of rinse water. An intake hose connected with the water supply is placed at the other end of this tank.

Several crates or dipping trays are required. They may be made with solid board ends and lath bottoms and sides, with the lath spaced slightly less than one-fourth inch apart to allow the washing solution to drain out of the tray rapidly and thoroughly. These trays may be equipped with handles to permit dipping without wetting the hands of

the operator. The completed trays should be given two heavy coats of asphaltum paint to lengthen the life of the trays and to promote run-off of excess acid.²³

Washing Solutions. Sweet cherries have been cleaned satisfactorily in Oregon by dipping the fruit in a 0.3% solution of hydrochloric acid (approximately $1\frac{1}{4}$ quarts of muriatic or commercial hydrochloric acid in 30 gallons of water). Cracking of the cherries was not observed unless a rain occurred during the previous night or immediately before picking the fruit. However, the cherries should be allowed to stand for an hour or more after picking to lessen the possibility of cracking.



Figure 29. Interior of a packing house for sweet cherries. (Courtesy of California Experiment Station.)

The trays holding the cherries are submerged in the tank of acid solution and agitated by moving the trays up and down as they are moved from one end of the tank to the other in a period of approximately three minutes. The tray then is lifted from the acid solution and rested on the drainboard of the acid tank to allow the excess acid to drain off. The tray of cherries is dipped and agitated in the rinse-water tank to rinse off remaining traces of the acid solution. After draining for about one minute, the trays may be emptied onto the packing table.²³

Acetic acid was found to be very satisfactory for both sweet and red cherries when used at a concentration of 3% without a wetting

agent. When wetting agents were added to the acetic acid bath, a 1% solution of the acid seemed to be just as effective as the stronger solutions. The addition of the wetting agents to the acetic acid bath also improved the finish of the fruit—the cherries were bright and attractive.²²

A one percent solution of hydrochloric acid successfully removed residues of sulfur, lead, and arsenic from red cherries in New Jersey, but it is reported that the addition of a small amount of a wetting agent enhanced the appearance of the fruit. When the wetting agent was employed, a 0.25% solution of hydrochloric acid plus 0.1% of wetting agent gave satisfactory results if the cherries were agitated in the acid bath for two to three minutes.²⁴

C. GRADING AND PACKING FOR FRESH MARKET

Cherries that are to be shipped to fresh fruit markets are sorted to remove fruits that contain the larve of curculio and the cherry fruit flies and fruits that show cracks, wind bruises, and brown rot. The sweet cherries, and occasionally the red cherries, are graded for size. The large packing plants are equipped with mechanical sizers.

Containers. Shallow containers are desirable for cherries since they obviate the necessity of deep packs that may injure fruits on the bottom layers. In general, the smaller and shallower of the containers designed for cherries should be used for the softer varieties.

The containers that are in general usage for packing cherries for shipment from the several areas of commercial production are listed in Table 17. The sources from which this table was compiled are not in complete agreement in listing dimensions and there are slight differences in dimensions for essentially the same container when used in different areas. The writer, has, therefore, taken the liberty of compromising some of the dimensions and they must be regarded as approximations or averages rather than exact in some cases. The table does not list all containers used for cherries.

Most of the sweet cherries that are grown for the fresh fruit market in the western states are packed in boxes or lugs that hold 10 to 20 pounds of fruit. The American type berry crate, holding 16 veneer till-type boxes, is often used for cherries produced in the eastern and north central states. Both the four-quart and the twelve-quart climax baskets (commonly used for grapes) are often employed for cherries produced in New York and in Ontario. Cherry boxes and

lugs used in Canada shall be one or other of the following inside dimensions: 13 x 6 x 3 inches; $16\frac{1}{8}$ x $13\frac{3}{8}$ x $5\frac{3}{4}$ inches, or 15 x $10\frac{3}{4}$ x $3\frac{1}{8}$ inches to be used with one-fourth-inch cleat.²⁵

Packing. The various boxes that are used for sweet cherries are usually packed with the boxes in inverted position so that the top, or face, layer may be arranged initially. This layer is usually packed

TABLE 17. CONTAINERS USED IN SHIPPING CHERRIES FROM DIFFERENT AREAS OF PRODUCTION^a

Designation	Inside dimensions, in.	Areas
Standard 12-basket crate (4) ^b	$27\frac{7}{8}$ x $13\frac{1}{2}$ x 18	California
Standard cherry box or 10-lb. cherry box (10)	$21\frac{1}{4}$ x 9 x $18\frac{1}{8}$	California, Oregon, Wash- ington, Idaho
Standard cherry box	$31\frac{1}{8}$ x $10\frac{3}{4}$ x 15	Canada
Standard cherry lug (11)	$3\frac{3}{4}$ x $11\frac{1}{2}$ x $16\frac{1}{8}$	California
Standard cherry lug (12)	$27\frac{7}{8}$ x 11 x $16\frac{1}{8}$	California
Standard cherry lug (12a)	$3\frac{3}{4}$ x $11\frac{1}{2}$ x $14\frac{1}{8}$	California, Michigan
15-lb. cherry box	3 x 11 x 18	Idaho, Washington
15-lb. cherry box	$41\frac{1}{8}$ x $8\frac{5}{8}$ x $17\frac{1}{4}$	Oregon
15-lb. cherry box	4 x 11 x 14	Oregon
Standard cherry lug box (22c)	$3\frac{3}{4}$ x $13\frac{1}{2}$ x $16\frac{1}{8}$	California
Standard lug box (25)	$4\frac{3}{4}$ x $13\frac{1}{2}$ x $16\frac{1}{8}$	California
Standard lug box (27)	$5\frac{3}{4}$ x $13\frac{1}{2}$ x $16\frac{1}{8}$	California, Oregon, Canada
20-lb. cherry box	$41\frac{1}{2}$ x 9 x 18 or 19	Idaho, Oregon, Washington
16-qt. crate	$71\frac{1}{2}$ x 11 x 22	Michigan, Ohio, New York, Pennsylvania, Wisconsin
12-qt. climax basket	$71\frac{1}{16}$ x 9 x 19 ^c	New York
4-qt. climax basket	$41\frac{11}{16}$ x $61\frac{1}{4}$ x 14 ^c	New York

^a Compiled from *U. S. Dept. Agr., Bur. Agr. Econ. Mimeo. 1932*; Assoc. of Amer. Railroads *Freight Container Bur. Tariffs, 1944*; *Agr. Code of Calif. 1947*; L. Havis, *U. S. Dept. Agr. Farmers Bull. 776* (1948); *Blue Book*, Produce Reporter Co., Chicago (1948); *The Packer Red Book*, The Produce Mercantile Agency, Kansas City (1948).

^b Numbers in parentheses are Agricultural Code of California container numbers.

^c Width and length measurements are outside dimensions at top of container.

so that cherries of uniform size are arranged in straight or diagonal rows, with the stems slanting in an upward direction. The pack thus presents a smooth and attractive appearance, with no stems in evidence, when the package is opened at the markets (Figure 30). The second layer also is usually arranged in systematic rows with the

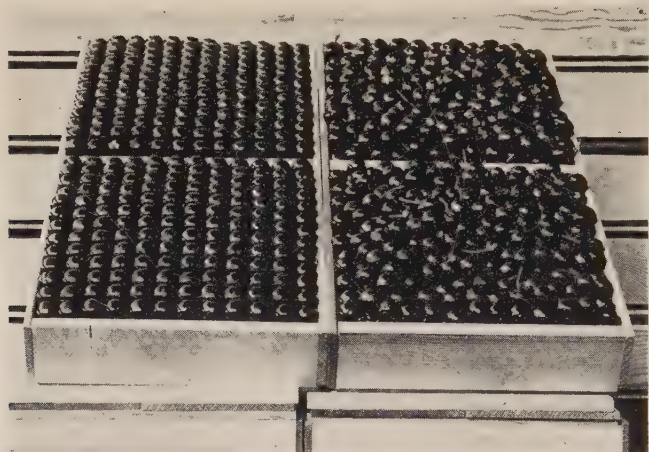


Figure 30. The standard box for sweet cherries. The box at the left shows the top view or face of the pack with good alinement. The box at the right shows the bottom view with no regular arrangement of the fruit. (Courtesy of California Experiment Station.)

cherries offset with, or nested with, the cherries of the first layer. The third layer is identical with the first, and the fourth is like the second layer.

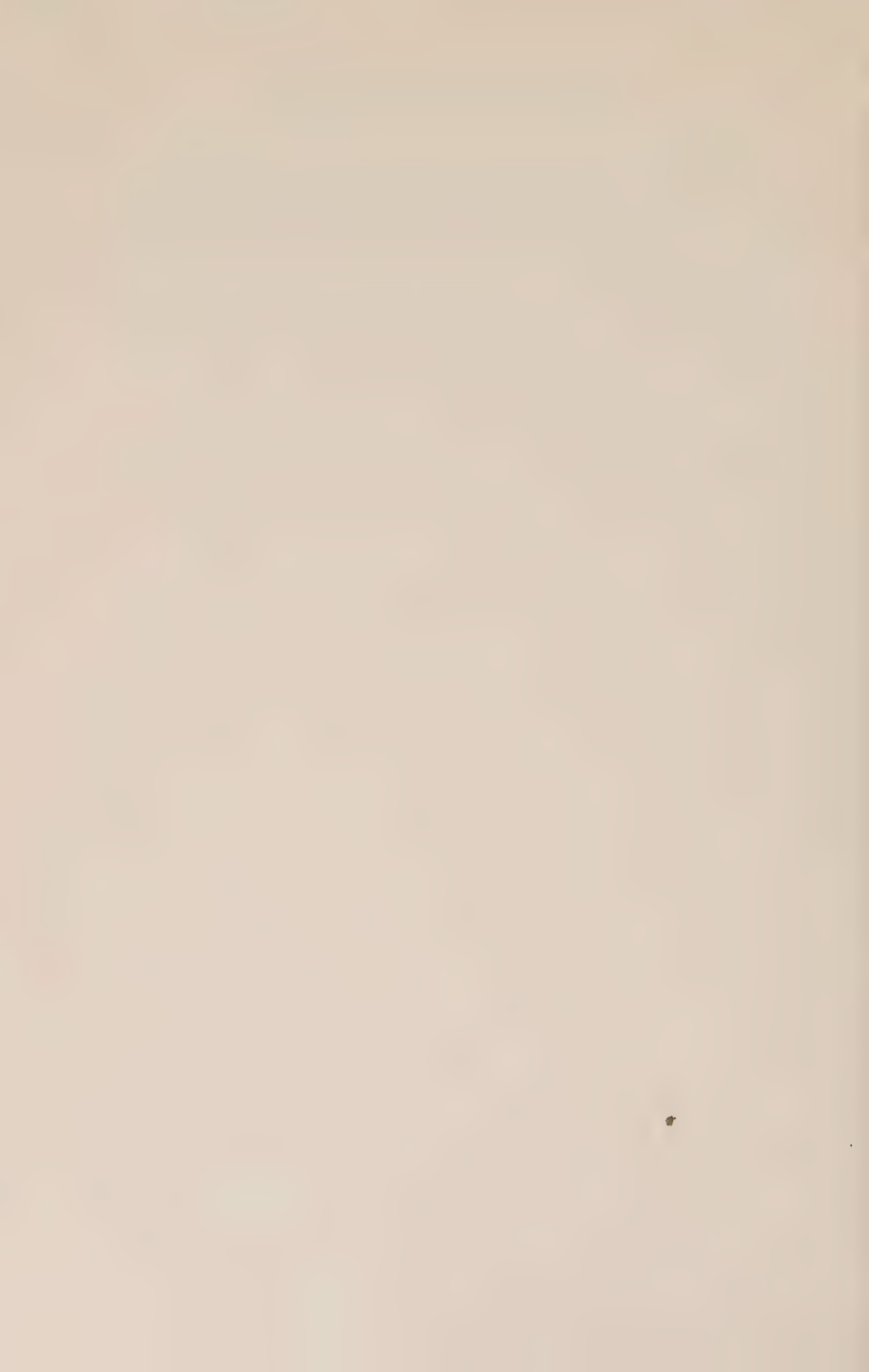
Some of the larger boxes and the lug boxes are packed with a face layer having a systematic or geometric arrangement and no definite arrangement for the balance of the container. This "face and fill" type of pack is common for 15- and 20-pound boxes. Cherries that are too small for tier or layer packing, those that are not uniformly sized, and those that may be over-ripe or otherwise not suitable for tier or layer packing in boxes are usually packed in lug boxes with no definite arrangement of fruits.

Cherry boxes are usually lined with paper before packing. Impregnating these packing materials with various chemicals to reduce decay during holding and transit periods has not proved entirely satisfactory and is not warranted where carbon dioxide treatments are employed.²⁶

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FACTORS AFFECTING THE POST-HARVEST LIFE OF THE CHERRY

Fruits continue to live after they are removed from the trees. In the process of living, certain chemical changes take place and these chemical changes are accompanied by respiration, a component phase of which is the intake of oxygen and the evolution of carbon dioxide. The rate of living can be measured by determining the rate of respiratory activity of the cherries.

Subjecting the fruits to low temperatures, or to certain modifications of atmosphere, slows down the rates of chemical change and respiration so that the life of cherries may be prolonged substantially. The real function of refrigeration or atmospheric modification, then, is to retard these chemical and physiological processes. These changes or life processes, however, cannot be stopped—they can only be retarded or slowed up.¹

Transportation of cherries, especially for long distances, is done in refrigerated cars or trucks and the refrigeration is sometimes supplemented by modification of atmospheric conditions. Thus, the period required for transportation under such conditions becomes a part of the storage period, and, in the case of cherries shipped to distant markets, it may constitute a substantial part of the after-harvest holding period.

1. Freezing Points of Cherries

Table 18 shows the average freezing points for mature fruits of the sweet cherry to be nearly four degrees lower than those for varieties of the red cherry. Furthermore, the freezing point for the Early Richmond variety of red cherry is slightly lower than that for the Montmorency, and the Bing sweet cherry is able to withstand slightly lower temperature than the Black Tartarian. Mature sweet

TABLE 18. FREEZING POINTS OF CHERRY FRUITS²

Variety	Region of production	Maturity	Freezing points, °F.		
			Maximum	Minimum	Average
Early Richmond	Eastern	Mature	28.3	27.6	27.9
Montmorency	Eastern	Mature	28.6	27.8	28.1
Black Tartarian	California	Immature	26.6	25.4	25.8
Black Tartarian	California	Mature	25.1	23.5	24.2
Bing	California	Immature	26.4	24.6	25.3
Bing	California	Mature	24.3	23.4	24.1

cherries have substantially lower freezing points than immature ones. It is apparent that there is a definite relationship between the sugar content of the fruit and its freezing point—the higher the sugar content, the lower the freezing point.

Rose et al³ state that the average freezing point for eastern-grown red cherries is 28.0°F. and that for eastern-grown sweet cherries is 24.7°F. compared to an average of 24.2°F. for western-grown sweets.

Table 18 shows that a considerable range of freezing points has been obtained in replicated tests made with the same variety. When freezing point determinations are used as a basis to determine the minimum temperatures to which the fruits may be exposed without resulting in injury, the maximum freezing points should be stressed. Thus, the maximum freezing point of 28.6°F. for mature Montmorency cherries should serve as a warning that it is not safe to allow the temperature of these fruits to drop appreciably below 29°F. If some of the cherries are immature, they might have ice crystals formed within them at even higher temperatures.

Refrigeration equipment is not infallible and sometimes thermometers are not placed in the coldest locations of refrigerated rooms. Hence, allowance should be made for a safety factor. When all factors are considered, it appears that red cherries should not be held at a temperature lower than 30°F. and that sweet cherries should not be stored in a room that may have a minimum temperature lower than 28°F.

2. Relation of Holding Temperature to Storage Life

Temperature and Useful Storage Life. A study of the storage behavior of 51 varieties of cherries during three seasons lead to the

conclusion that the lower the temperature, down to 32°F., the better the keeping quality of the fruit. In general, the optimum storage period for cherries held at 32°F. was 14 days. This permitted an additional five-day marketable period. At 36°F., the optimum storage period was 12 days; at 45°F. it was eight days, and at 65 to 75°F., it was only four days plus an additional four-day marketable period. It was concluded that cherries may be kept three times as long at 32°F. as at 65 to 75°F. Furthermore, cherries stored immediately after harvest could be kept in optimum condition for 15 days at 32°F., while a 30-hour delay between harvest and storage shortened the optimum storage time to ten days.⁴

The keeping quality of the Montmorency variety in New York at various temperatures was based on freedom from both mold and fermentation and the loss of flavor. At 32°F., the cherries were held satisfactorily for 45 days; at 50°F., they kept for 15 days, and at 72°F., they could be held for only 60 hours.⁵

Kessler⁶ observed the behavior of 23 varieties of cherries stored at temperatures ranging from 0°C. to 2°C. and reports there was some loss of flavor among fruits held at the 0°C. level. On the other hand, Gerhardt and his associates⁷⁻¹⁰ have employed storage at 31°F. in many of their investigations without ill effects. They were able to control both mold and decay at 31°F. and found no evidence of dullness or sponginess in Bing cherries stored at this temperature.

Respiration Intensity. Respiratory intensity is the generally accepted index of metabolism. This can be determined by measuring the rate of carbon dioxide liberation by the fruits. Table 19 shows the rate of carbon dioxide evolution in terms of milligrams per kilogram of fruit per hour for Lambert cherries held at three levels of temperature on the first, third, and eighth days. At the end of eight days, fruit held at 36°F. respired approximately 26% faster than that stored at 31°F. The respiration rate at 45°F. was 70% greater than at 36°F. and 115% greater than at 31°F. These data may be interpreted in terms of probable lengths of optimum storage at the designated temperatures. If, for example, the cherries could be held successfully for 15 days at 31°F., they might be expected to reach the end of their storage life in 12 days at 36°F. or in seven days at 45°F.

The heat of respiration of cherries at 60°F. is about eight times that at 32°F.³ This indicates that the respiratory activity, or rate of living, at 60°F. is about eight times that at 32°F., and that cherries may be held eight times as long at 32°F. as they can be kept at 60°F.

Delayed Storage. These relationships between temperature and rate of living or length of optimum storage life apply at any stage in the life of harvested cherries. A delay of several hours between harvesting and storage at low temperature may shorten appreciably the optimum storage period for cherries. Sweet cherries with 15 days of optimum storage life at 32°F. following immediate storage were found to have only ten days of optimum storage life if there was a delay of 30 hours prior to storage.⁴

TABLE 19. RESPIRATION OF LAMBERT CHERRIES AS INFLUENCED BY STORAGE TEMPERATURE⁸

Length of storage, days	Respiration, mg. CO ₂ per kg./hr.		
	Stored at 31°F.	Stored at 36°F.	Stored at 45°F.
1	5.87	6.15	14.30
3	5.38	6.44	11.60
8	5.80	7.31	12.46
Ave.	5.68	6.63	12.78

Prompt removal of field heat is one of the important contributions to the improved quality of sweet cherries⁸ and rapid cooling has never proved harmful, despite opinion to the contrary.¹¹

Summary. It is apparent that investigators have found that the optimum storage temperatures for cherries are 31 to 32°F. These temperature levels are the most satisfactory from the standpoints of preservation of quality and freedom from development of mold and decay. The cherry is very perishable and must be cooled to these levels of temperature, immediately after harvest to provide the maximum length of storage life.

3. Humidity and Transpiration

Nearly all of the post-harvest weight losses of cherries are due to loss of water through transpiration. Loss of weight or shriveling of cherries after harvest is the second most important factor in determining the length of time that fruits may be kept in optimum condition. It is especially important with cherries because the fruit loses both firmness in flesh and brightness of color when appreciable amounts of water are lost through transpiration. Furthermore, the stems of cherries are extremely susceptible to shriveling and an accompanying discoloration associated with loss of water.

Relative Humidity. Loss of weight due to transpiration is inversely proportional to the relative humidity of the environment in which the cherries are being held. Relative humidity is the percentage of moisture in the atmosphere compared to saturation or the dew point. A relative humidity of 90% indicates that the atmosphere contains 90% of the moisture required for a saturated condition. It may be determined from temperature readings of both wet and dry bulb thermometers of a sling psychrometer or by hygrometers.

A warm atmosphere has a greater moisture-holding capacity than a cool one. Therefore, an atmosphere at 50°F. and 85% relative humidity contains much more moisture than one at 40°F. and the same relative humidity. This relationship is important in the storage of fruits because any increase in temperature of a storage room is accompanied by a decrease in relative humidity, even though the absolute amount of water in the atmosphere remains the same.

Loss of Weight of Fruit. The definite relationship between maturity and rate of weight loss in storage for most kinds of tree fruits does not seem to hold for cherries. Weight loss was not found to be correlated with maturity of Bing and Lambert sweet cherries in Washington,¹⁰ and harvesting Ontario grown Victor, Windsor, and Montmorency fruits one week before optimum maturity and at optimum maturity resulted in no significant difference in weight losses during one week of holding.¹²

A striking relationship was observed between relative humidity and weight losses for Napoleon fruits that were stored for 28 days at 66°F. A relative humidity of 50 to 60% in a storage without forced air circulation resulted in a weight loss of 48.2%, while a relative humidity of 80 to 85% gave a loss of 11.1%. The former cherries were much shriveled and more or less moldy, while the latter were plump and turgid and showed very little mold at the end of the 28-day period.¹³

Forced air circulation in a storage room operated at low relative humidity (50 to 60%) and high temperature practically dried the fruits in 28 days.¹³ On the other hand, no correlation between velocity of air movement in the storage room and weight losses of fruits occurred in low temperature rooms in which the relative humidities ranged from 85 to 90%.⁸ Apparently, the rate of moisture losses due to velocity of air movement is not appreciable if the relative humidity of the holding room is maintained at a very high level.

Temperature is of secondary importance in determining the rate of weight losses in cherries, and such losses are proportional to temperatures. The percentages of weight losses (fresh weight basis) for Bing cherries held for nine days at relative humidities of 85 to 90% and at 45°F., 36°F., and 31°F. were 4.8, 3.8, and 3.1, respectively, while those for Lambert were 5.7, 4.0, and 3.9 for the respective temperatures. The data indicate average daily weight losses ranging from 0.34% to 0.65% at temperatures of 31 to 45°F. and relative humidities of 85 to 90%.⁸ Average daily weight losses of 0.5 to 0.8% were recorded during a seven-day holding period at "room temperature" for three varieties in Ontario.¹²

Relative humidity seems to be the most important single factor associated with rate of loss of weight in stored cherries. When storage temperatures are maintained at 31 to 32°F., a relative humidity of 85% may be ample, but as the temperature level is raised, the relative humidity should also be increased slightly to prevent excessive loss of moisture through transpiration.

Loss of Moisture and Discoloration of Stems. The stem of the sweet cherry is extremely susceptible to shriveling and discoloration and special precautions are necessary to preserve greenness and freshness during storage and transit. The rate of moisture loss in stems does not appear to be influenced appreciably by storage temperatures nor by the rate of cooling of the cherries.^{8,10,14} The stems of cherries cooled in one hour in air having a velocity of 770 feet per minute and then held at low temperature for 6½ hours did not lose more moisture than did fruit cooled in still air in 7½ hours.¹⁴

The rate of moisture loss in stems is more rapid at a relative humidity of 50 to 60% than at 80 to 85%.^{8,15} Moisture loss seems to be evenly distributed throughout the length of the stem.¹⁵ Waxing of stems has not been beneficial in reducing rate of loss of moisture and was responsible for some injury and discoloration in one experiment.^{10,15}

Browning of the stems is not due to a loss of chlorophyll; the chlorophyll is masked by the brown pigments. Rapid browning follows any physical injury to the stem and this is accompanied by accelerated shrivel. The browning is probably the result of an altered permeability of injured cells and it is thought that the enzyme responsible for the browning is polyphenol oxidase.¹⁵

It is evident that browning of stems and the accompanying rapid

shriveling may be held in check by careful handling to avoid bruising of the stems and by holding the fruit at relatively high humidities during cooling, during storage or transportation and during post-storage or post-transit periods.

Sweating of Fruit. When fruit is removed from a low temperature to a warm environment, moisture is likely to condense on the cool surface of the fruit. This is more marked when the warm air is also humid. Condensation of moisture on fruit is called "sweating" by commercial handlers of fruit. Sweating produces a dull appearance on cherries displayed for sale soon after they are removed from iced cars.³ It can be prevented by allowing the fruit to warm up gradually, but such a practice is rarely practicable.

Many shippers believe that sweating of cherries leads to an increase in the amount of decay developing during transit. Most of them demand that cars be cooled to a temperature lower than that of the incoming fruit at loading time to prevent sweating and subsequent danger of decay.¹⁶

Condensation of moisture on Washington-grown cherries⁹ having a temperature of 40°F., or lower, however, failed to increase the amount of decay. Moisture-laden sweet cherries were stored in 17-pound lugs at 40°F. and 85% relative humidity where the air movement was at the rate of 75 to 100 feet per minute. An occasional droplet of water was found on the fruits after six hours of storage; only a trace of water film was found after nine hours, and none after ten hours of storage. The investigators also found that the time required for spore germination at 40°F. is longer than the interval that the moisture remains on the fruit. They conclude that temporary condensation of moisture on cherries at 40°F. does not increase the amount of decay because the moisture film is not retained long enough to permit the germination of spores.⁹

Apparently, sweating is not a serious problem in the handling of cherries. Sweating seldom continues for a period that is of sufficient length to stimulate the germination of spores.

4. Air Circulation

Some handlers of cherries are of the opinion that high air velocities in low temperature storage rooms cause the fruit to become dull in color and spongy in texture and impairs the keeping quality. These

characteristics of fruits would imply that serious weight losses occur during storage in rooms having forced air circulation. Experimental evidence does not support the contention that loss of weight in cherries is influenced by the velocity of air movement in the storage room.

Cooling to any desired level can be accomplished much more rapidly under forced air circulation than in still air. In an experiment sweet cherries were cooled from 70 to 33°F. in 11 hours in a room held at 31°F. and having an air velocity of 375 feet per minute, whereas 16 hours were required to lower the temperature of the fruit to 34°F. in still air. Furthermore, cherries were cooled from 70 to 52°F. as rapidly in air that was forced to circulate at 44°F. as in still air at 32°F. In general, it required 1.9 times as long to cool the fruit in still air as in rooms equipped with forced air circulation.¹⁰

5. Market Diseases

Descriptions and methods of control for some of the more important diseases of the cherry are presented in Chapter VII. Some of these diseases may cause substantial losses of fruit during handling, storage, and transit. The more important market diseases are brown rot (*Sclerotinia fruticola* or *S. laxa*), blue mold (*Penicillium expansum*), gray mold (*Botrytis* sp.), and Rhizopus rot (*Rhizopus nigricans*). The first two of these four are mentioned frequently in literature pertaining to the storage and transportation of cherries. Diseases that cause decay are the principal factors in determining the life of cherries after removal from the trees.

Most of the fungi that cause diseases of cherries after harvest are inhibited in development by low temperature, but some of them make some growth even at temperatures as low as 32°F.^{17,18}

The amount of growth made by blue mold seems to be inversely proportional to the temperature of the fruit, when the fruit temperature is below 50°F. Serious losses may occur even at temperatures between 40 and 50°F. Growth of the fungus is not prevented at temperatures of 32 to 36°F., but it is greatly inhibited at such levels of temperature.¹⁸

The relationship between temperature and the development of brown rot is essentially the same as that for blue mold. Gray mold development also follows a similar pattern. Rhizopus, however, has a critical temperature of approximately 50°F. It will cause little damage at 50°F. and no damage where the fruit temperature is as low as 45°F.^{17,18}

Relative humidity does not seem to be a factor in mold development on cherries. The organisms causing molds gain entrance to the fruits through skin abrasions and, if these abrasions are present, molds will develop at low as well as at high humidities, providing temperatures are favorable.¹³

One of the most effective methods of inhibiting the development of molds and decay, where it is impractical to maintain low temperature levels, is to modify the content of the atmosphere in which the fruits are held during the storage period or prior to transportation at prevailing transit temperatures. The effects of various modifications of the atmosphere on the life of cherry fruits is presented in subsequent sections of this chapter.

The amount of decay that develops on cherries after harvest may be associated with certain pre-harvest factors. The cumulative effect of successive rains immediately prior to the time the fruits are harvested may cause the amount of cracking and decay to be more or less proportional to the time the fruit is held on the trees subsequent to the initiation of the rain period.⁹ Decay also was found to be more prevalent in lots of cherries that were more mature at harvest than in lots harvested a few days earlier.¹⁰

6. Modified Atmosphere

Investigators began to study the possibility of supplementing refrigeration with modified atmospheres during the early portion of the third decade of the current century. Within ten years the results were so successful that the practice of supplementing standard refrigeration with substantial concentrations of carbon dioxide during transit was adopted rather generally for commercial shipments originating in Pacific Coast areas. It is claimed that this practice has improved the marketability of sweet cherries grown in those regions for the eastern markets (see Chapter XI).

Tolerance of Cherries to Carbon Dioxide. Cherries show a high degree of tolerance to atmospheres containing rather large concentrations of carbon dioxide.¹⁹ Bing and Lambert cherries have been held at 60°F. for 12 days in an atmosphere containing 40% carbon dioxide without impairment of dessert quality. Mold and decay, however, were not controlled under these conditions and when the concentration was increased sufficiently to control mold at a temperature of 60°F., off

flavors resulted. Flavor impairment even occurred when the atmosphere contained only 25% carbon dioxide at a fruit temperature of 65°F. When the temperature was maintained at 45°F., it was possible to have 40% carbon dioxide in the atmosphere for a period of 20 days without affecting the quality of the fruit. Increasing the holding period to 31 days under these conditions, however, resulted in abnormal flavor and impaired quality.¹⁸

Respiration Intensity in Relation to Carbon Dioxide. Respiration intensity of sweet cherries can be depressed by increasing the concentration of the carbon dioxide in the atmosphere of the storage room. The degree of repression of respiration is a function of the permeability of the fruit tissues to carbon dioxide and of the concentration of the carbon dioxide in the air.⁸

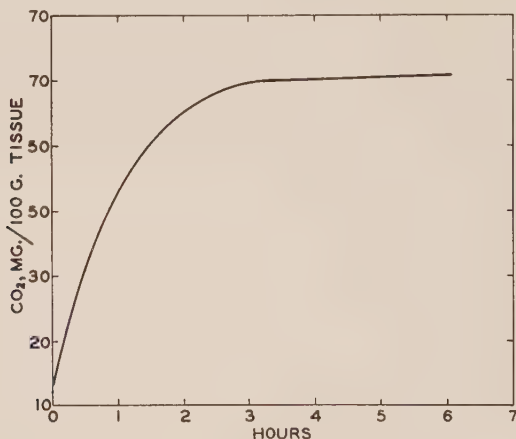


Figure 31. Carbon dioxide in the internal atmosphere of Lambert cherries during storage in 20% carbon dioxide at 36°F.⁸

Figure 3 shows that Lambert cherries accumulated 2.3 times their normal intercellular content of carbon dioxide in one-half hour after being stored at 36°F. in an atmosphere of 20% carbon dioxide. The partial pressure of the carbon dioxide in the internal atmosphere of the fruit reached an equilibrium with that of the storage air after three hours of storage. At that time, the carbon dioxide content of the internal atmosphere was approximately 4.5 times that in comparable fruits stored in normal air at the same temperature.

Lowering the concentration of the carbon dioxide from 20% to 10% reduced the concentration of the intercellular carbon dioxide approximately 50%.

After the fruit that had been stored for 15 hours in 20% carbon dioxide was removed from storage, the carbon dioxide content of the internal atmospheres of the cherries dropped in one hour from 60.2 milligrams to 13.1 mg. per 100 g. of tissue, or to the level of the controls. This indicates that the carbon dioxide in the internal atmosphere of cherries is dissipated into normal air much more rapidly than it can be accumulated during storage in an atmosphere containing 20% carbon dioxide.⁸

Effect of Carbon Dioxide on Chemical Constituents. Holding both sweet and red cherries at 35°F. in an atmosphere containing 47% carbon dioxide for one to three days had no significant influence on the percentage of reducing sugars or on the percentage of total sugars.²⁰ Subjecting Early Richmond fruits to an atmosphere containing 50% carbon dioxide for 25 hours did not effect the acidity²¹ but in another experiment with sweet cherries rather high concentrations of carbon dioxide depressed the acidity slightly.²² These findings might be anticipated since cherries undergo little change in chemical content when held in air after removal from the trees.

Responses to Various Levels of Carbon Dioxide. Allen²³ reported that all lots of Bing and Napoleon cherries held at 32 and 45°F. in air and in various concentrations of carbon dioxide had normal flavor and appearance at the end of ten days. He noted, however, that the amount of decay was reduced more than 50% for the lots held at 45°F. when the atmosphere contained 10 to 60% carbon dioxide. Mold growth did not seem to be correlated consistently with the concentration of carbon dioxide. Allen states that the general condition at the end of ten days of the fruit held at 45°F. in a carbon dioxide atmosphere was better than that held in air at 32°F.

In a comprehensive investigation of the storage of Bing and Lambert cherries as influenced by carbon dioxide, it was found that cherries held at 45°F. in atmospheres containing either 40 or 25% carbon dioxide were firmer, brighter, and freer from decay at the end of 20 days than those stored in air at 32°F. Holding the cherries for 31 days under the former conditions, however, resulted in abnormal flavor and quality impairment. The higher concentration gave slightly better control of decay than 25% carbon dioxide but the latter level

of carbon dioxide gave a high degree of fungus control and it allows a wide margin in tolerance to carbon dioxide. When the concentration of carbon dioxide was 10%, serious decay developed during the 20-day holding period. A 15% level of carbon dioxide and a temperature of 40°F. inhibited mold growth with Lambert for 10 days and was nearly three times as effective as air at 32° F. during a holding period of 22 days. In one comparable test, 45°F. and 40 or 25% carbon dioxide was found to be better than air at 31°F. in preventing decay.

A concentration of 20% carbon dioxide at a temperature of 40°F. provided the most favorable environment of several tried at Cornell University for the holding of Schmidt, Napoleon, and Windsor cherries.²⁴ Reducing the oxygen level did not appear to improve the keeping of the cherries. These studies indicated that three weeks is about the limit of the storage period for the most favorable combination of temperature and carbon dioxide.

Sweet cherries were held for nine days under various conditions and then removed to normal air at 65°F. to simulate conditions encountered in transcontinental shipment and marketing. Complete control of mold for the 11 days resulted when the storage environment was air at 31°F. or was a 10 to 20% carbon dioxide atmosphere at 36°F. Good control followed storage at 5% carbon dioxide and 36°F. or 20% carbon dioxide and 45°F. The best control of brown rot resulted from 20% carbon dioxide and a temperature of 36°F. The treatment that ranked second was air at 31°F. and this was followed by carbon dioxide at 20% and 45°F. At a temperature of 36°F., the amount of decay was five times as great in air as it was in 20% carbon dioxide at the end of five days.⁷

The temperature levels and concentrations of carbon dioxide employed in the investigations just summarized differ somewhat and it may not be possible to draw specific recommendations from them that are not subject to modification when further work is reported. It appears, however, that sweet cherries may be kept in good condition and that mold and decay can be inhibited satisfactorily for approximately three weeks in air at 31°F. Such a temperature may be maintained in cold storage rooms, and transit temperatures in the low thirties are practical in freight cars equipped with fans that are driven from the car wheels.

Some other favorable environmental conditions for a storage period of three weeks appear to be: 25 to 40% carbon dioxide at

45°F.; 20% carbon dioxide at 40°F.; and 10 to 20% carbon dioxide at 36°F.

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PRETRANSIT TREATMENTS AND TRANSPORTATION

1. Prestorage and Pretransit Treatments

Investigators have long been interested in the development of possible treatments that may be provided for cherries immediately after harvest, or prior to shipment, which might prolong the life of the fruit or retard the rate of deterioration during transit at the levels of temperature that prevail in refrigerator cars. Some of the more important prestorage or pretransit treatments are precooling, a form of precooling known as hydrocooling, and subjecting the fruits to rather high initial concentrations of carbon dioxide.

A. PRECOOLING

Precooling has been defined as a form of refrigeration employed for the rapid removal of the field heat from fruit before shipping, mainly to reduce the temperature of the fruit to a point where ripening will be retarded materially and mold growth and decay prevented or reduced substantially.¹ The field heat is removed as soon as possible after harvest and rapid cooling continues long enough to reduce the temperature of the center of packages to a suitable carrying temperature.

Precooling western-grown sweet cherries was advocated in 1916 when it was observed that a substantial reduction in decay occurred when the cherries were precooled to 40°F. prior to a 10-day transit period.² Concessions granted by the rail carriers in 1932 and 1933, that permitted fruit to be shipped with fewer re-icings in transit and otherwise modified icing services, paved the way for the economic solution of the precooling problem. The proportion of shipments that were precooled immediately increased substantially as indicated by a report that 60 to 100% of the cherries shipped from California by some companies in 1934 were precooled.¹

Methods of Precooling. The customary precooling procedure in the Pacific Northwest for sweet cherries destined for shipment is to cool them overnight in lug boxes to temperatures between 36 and 40°F., move them to the packing house for sorting and packing, and then, after packing, return them to refrigeration where they are cooled to temperatures ranging upward from 32°F. before shipment.³

Precooling may be done after the packed fruit is loaded in refrigerator cars or it may be accomplished in storage rooms. If ice refrigeration is employed for precooling loaded refrigerator cars, the bunkers are iced to near capacity, 400 to 500 pounds of salt are added to lower the temperature of the melting ice and to increase the rate of melting, and portable, motor-driven fans are installed at the upper openings of the bulkhead walls of non-fan cars, during the cooling period, to force the air over and through the load and back through the ice more rapidly than would occur normally. The fruit may also be cooled in refrigerator cars by the employment of special precooling refrigeration equipment located along the track-siding. Similar procedures may be used prior to truck transit. Mechanical refrigeration is employed for warehouse precooling.

Rates of Temperature Reduction during Precooling. Allen and McKinnon¹ reported that 10 to 15 hours were required to cool the cherries near the outside of packages from a temperature of 65–70°F. to 35°F. in refrigerator cars where the circulating air temperature was maintained at 33 to 30°F. The fruit in the center of the packages was 10 to 13°F. higher than that near the edges at the end of four hours and 1 to 5°F. higher at the end of 18 hours. A period of 24 hours was considered necessary for complete cooling of the fruit in the center of the packages.

Rates of cooling in both refrigerator cars and storage rooms were found to be 2.0 to 3.5°F. per hour for cherries in the centers of packages, and 3.0 to 4.0°F. per hour for fruit near the edges of the containers over a period of eight to ten hours. The average cooling rate for both centers and edges of boxes over a period of 16 to 20 hours was slightly less than 2°F. per hour.¹

The above cooling rates were obtained in moderate air circulation. When the velocity of air movement was slow (50 to 75 feet per minute), fruit temperatures in the centers of packages were 5 to 13°F. higher than in comparable packages in air circulating at a velocity of 250 feet per minute.¹

Gerhardt and Hukill³ compared rates of cooling for Bing cherries harvested at two stages of maturity, in still air and in an air blast adjusted to 375 feet per minute, and at air temperatures of 31 and 44°F. After precooling, the cherries were held for 10 days at the respective precooling temperatures and a relative humidity of 80 to 82% to simulate transit conditions subsequent to precooling. The more mature lots of cherries were dark mahogany red when harvested and contained 22.3% soluble solids, while fruits representative of

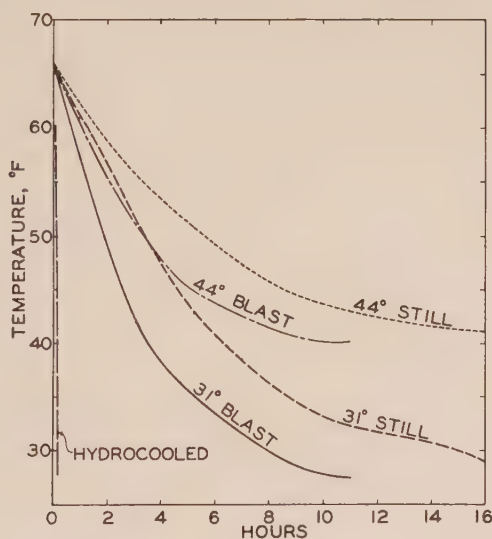


Figure 32. Precooling rates for packaged Bing cherries at 44 and 31°F. in still air and in air moving at a velocity of 375 feet per minute and hydrocooling individual fruits in a water bath at 32°F. All the curves shown become straight lines when plotted on semi-logarithmic charts.³

early maturity were pie-cherry red and had only 16.2% soluble solids. All lots were packed in five-pound wooden boxes with standard paper liners.

The rate of cooling was not influenced by the maturity of the fruit. Typical rates of cooling for the mature fruit in still and moving air at temperatures of 31 and 44°F. are shown in Figure 32. It is evident that the rate of cooling in either still air or moving air is proportional to the difference in the temperatures of air and fruit. Thus, if the air temperature is 20°F. lower than that of the fruit, cooling

will be twice that obtainable with a temperature differential of 10°F . This accounts for the fact that the amount of cooling during each successive hour grows less and less and also for the faster rate of cooling in air at 31°F . than in air at 44°F . When the rate of cooling curves shown in Figure 32 are plotted on semi-logarithmic paper, each of them, including the one for hydrocooling, becomes a straight line, further emphasizing the fact that cooling in degrees per hour is proportional to the temperature differential of air and fruit.

Figure 32 shows that the rate of cooling in air moving at 375 feet per minute was approximately 1.9 times that in still air, emphasizing the importance of forced air circulation in all precooling. During the first four hours of precooling from 70 to 50°F ., packaged fruit cooled as much in the air blast at 44°F . as in the still air at 31°F . On the other hand, it is obvious that 20 to 25°F . of field heat may be removed from cherries in a comparatively short time in cold storage warehouses that do not have rapid circulation of air.

The moisture content of the stems was not influenced by the velocity of air movement, the rapidity of cooling, or by the differences in storage temperature subsequent to precooling. Loss of weight of the fruit during storage was not correlated with the velocity of air movement during precooling, but weight losses were substantially greater for the cherries held at the higher temperature level. Air movement during precooling did not seem to be a factor in the development of decay, but decay was much more prevalent in all pre-cooled lots stored at 44°F . than for lots held at 31°F .

Dewey⁴ completely cooled Schmidt and Montmorency cherries in 30 to 50 minutes in air blast tunnels in air at 1 to 2°C . while more than seven hours were required in still air to reduce the temperature of the fruits to the same level.

Sainsbury⁵ loaded pallets with 60 15-pound lugs of cherries and cooled them 6.5 to 26 times faster in tunnels having air velocities of 300 to 800 feet per minute than was possible in rooms equipped to circulate air at 70 to 120 feet per minute. He suggests an air velocity of 800 feet per minute for tunnel cooling of pallet loads.

Cooling rates for consumer-size packages in master cartons are relatively low. Master cartons containing 24 one-pound film packages of cherries cooled only 40% as rapidly as cherries that were face-packed in 15-pound lugs.⁶

Refrigerator cars equipped with fans are capable of maintaining

temperatures of 33 to 36°F., or even lower if desired, in transcontinental shipments of cherries that are precooled to temperatures well below 40°F. It, therefore, appears that precooling cherries to a temperature level of 32 to 36°F. is advisable for such shipments.

B. HYDROCOOLING

Hydrocooling is a kind of precooling which employs refrigerated water rather than air as the cooling medium. The fruit may be immersed in a water bath or water may be flooded over and through the product either before or after packaging. The water may be refrigerated with melting, crushed ice or with direct expansion coils of a mechanical refrigeration system. In either case, the temperature of the cooling medium should be maintained at 32°F. or slightly higher.

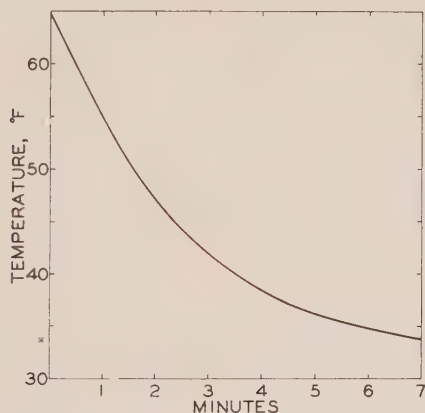


Figure 33. Hydrocooling rate for Bing cherries immersed in water at 32°F.³

Only seven minutes were required to reduce the temperature of Bing cherries from 65 to 33.7°F. when they were immersed in a water bath of melting ice maintained at 32°F. The temperature curve as shown in Figure 32 is almost vertical for hydrocooling but when the time interval is changed to that used in Figure 33, the form of the curve for the rate of cooling becomes similar to those for cooling in air (Figure 32). The cherries cooled 145 times as fast in ice water at 32°F. as in still air at 31°F. and about 94 times as fast as in air at 31°F. moving at 375 feet per minute.

There were no consistent differences between hydrocooled cher-

ries and those precooled in air at 31°F. in respect to the condition of the stems, or percentage of decay. On the other hand, the loss in weight in the fruit during subsequent storage was reduced somewhat by rapid cooling in water.

The hesitancy of shippers to employ hydrocooling for the rapid removal of field heat from sweet cherries is based largely on the assumption that free moisture on the surface of the fruit may increase both decay and cracking. Table 20 shows that mature Bing cherries

TABLE 20. RELATION OF HYDROCOOLING MATURE BING CHERRIES AT 32°F. TO CRACKING AND TO THE DEVELOPMENT OF DECAY DURING SUBSEQUENT STORAGE⁷

Treatment	Type of pack	Percentage cracked fruit ^a	Percentage of Decay	
			10 days at 40°F.	Plus 2 days at 65°F.
Check ^b	Dry	0	2.7	4.3
Hydrocooled for 15 min.	Wet	0	2.1	7.3
Hydrocooled for 15 min.	Dry	0	4.5	6.2
Hydrocooled for 30 min.	Wet	0	1.8	8.0
Hydrocooled for 30 min.	Dry	0	3.1	7.7
Hydrocooled for 6 hours	Wet	9.6	1.0	13.0
Hydrocooled for 6 hours	Dry	6.0	3.7	14.1
Hydrocooled for 14 hours	Wet	66.1	6.0	55.9
Hydrocooled for 14 hours	Dry	63.5	8.2	51.1

^a After storage at 40°F. for 10 days.

^b Held continuously in air at 40°F.

may be hydrocooled for at least 30 minutes without cracking or without appreciable increase in the amount of decay developing during subsequent transit at 40°F. Furthermore, it apparently made little difference whether the hydrocooled cherries were packaged wet or dry. The appearance of the hydrocooled samples was comparable to that of fruit cooled in air at 32°F. with a relative humidity of 85%.

C. PRETRANSIT CHARGES OF CARBON DIOXIDE

The storage of cherries in modified atmospheres is discussed in Chapter X. Carbon dioxide also may be introduced into refrigerator cars after the loading is completed. The cars then may be held at shipping point for a time after initial charging with carbon dioxide to permit maintaining the desired level of carbon dioxide, or they may be shipped immediately after charging. In either case, the con-

centration of carbon dioxide is gradually reduced after the charging is completed, due to the fact that refrigerator cars are not gas-tight.

The better refrigerator cars available in 1939 would retain a maximum of not over 15% carbon dioxide.⁸ Later a car of sweet cherries was charged with enough carbon dioxide to provide a concentration of 20 to 24% and then was held at the shipping point in California for four to five hours prior to starting eastward. On arrival at Chicago the concentration of carbon dioxide was 7.5 to 10% and when the car arrived at New York it still had an atmosphere containing 6 to 8.5% carbon dioxide. Under these conditions, the rate of decay was reduced consistently, even after the fruit was removed to warm rooms at the terminal market. The color was both lighter and brighter than for the cherries transported in air under otherwise similar conditions.⁹

In another test, Bing, Lambert, and Napoleon cherries were subjected to various initial concentrations of carbon dioxide for 48 hours at initial temperatures that ranged from 63 to 70°F., and then the fruits were held in air at temperatures of 50 to 63°F. for 96 to 196 hours. In general, decay was held in check as well by immediate exposures to atmospheres containing 30% or more of carbon dioxide as by immediate storage at 32°F. The carbon dioxide-treated lots generally rated better in flavor at the end of the holding periods than the untreated lots.¹⁰

D. WAXING AS A PRETRANSIT TREATMENT

Waxing of some kinds of fruits to reduce weight losses due to transpiration has become standard practice. Since the cherry has a large surface area in proportion to the volume, it would appear that waxing might be employed to advantage to reduce weight losses occurring in transit and subsequent marketing.

Claypool¹¹ found that several kinds of available waxes were beneficial with the Bing variety. Most of the commercial waxes designed for fruits contain various proportions of paraffin and carnauba. Waxes containing carnauba and paraffin in a ratio of about 3:1 reduced the water loss from Lambert cherries about 33% during a ten-day holding period; those having a carnauba:paraffin ratio of about 2:1 reduced the moisture loss about 42%, and when paraffin was used without carnauba the loss was reduced about 53%.

Waxing with a carnauba-paraffin mixture provided a very at-

tractive, bright finish on cherries. Claypool states that waxing might well be justified on the basis of the improvement in appearance alone. Decay is not overcome by waxing, and, in fact, may even be aggravated when a heavy spore load is sealed under the layer of wax.

While the experimental evidence indicates some rather outstanding advantages for waxing, the process has not been adopted as a preshipment treatment for cherries.

2. Transportation of Fresh Cherries

More than 2500 carloads of fresh sweet cherries move from production areas in the Pacific Coast states in refrigerator cars during seasons when the crop is good in those areas. The orderly movement of this number of cars from the many shipping points demands organized cooperation on the part of the shippers and the carriers to provide cars, in at least good condition, where and when they will be needed to handle this highly perishable commodity. All of the cars must be iced to capacity and many of them must have salt added to the ice about 24 hours prior to the time that loading is to start. Then the loading must be in an orderly manner that will comply with tariffs established by the carriers.

A. REFRIGERATOR CARS

Both freight refrigerator and express refrigerator cars have been used to transport sweet cherries from the western areas of production to midwestern and eastern markets. The express refrigerators have been moved in both freight trains and in passenger train service. About 65% of the sweet cherries shipped from the Pacific Northwest in 1949 moved as express shipments.

The standard freight refrigerator car is 40 feet long while the express refrigerator is 10 feet longer. The express refrigerator car can accommodate a minimum load of 27,500 pounds in seven full layers and a partial eighth layer of 15-pound boxes, while a freight refrigerator must be loaded nine and ten layers high to accommodate the same number of boxes. It was thought that the lower height of loading permitted better refrigeration of the top layers in the car. Furthermore, the average express refrigerator was deemed superior in construction, especially in regard to heat leakage through the envelope, than the average freight refrigerator. The latter, however, has

undergone much improvement in recent years and many are equipped with fans that are driven from the car wheels.

The general principles employed in construction of the two kinds of cars are similar. The outer sheathing may be wood or steel. The amount of insulation in the envelope varies from three to six, or even seven inches, but most of the cars currently available for shipment of fresh fruits have three to 3.5 inches of blanket-type insulation fitted between the frame members of the walls, floor, and ceiling of the cars. Some of the newer cars have four to six inches of insulation consisting of two or three different kinds of insulating materials. The cars having the greater amount of insulation are designed mainly for the transportation of frozen foods.

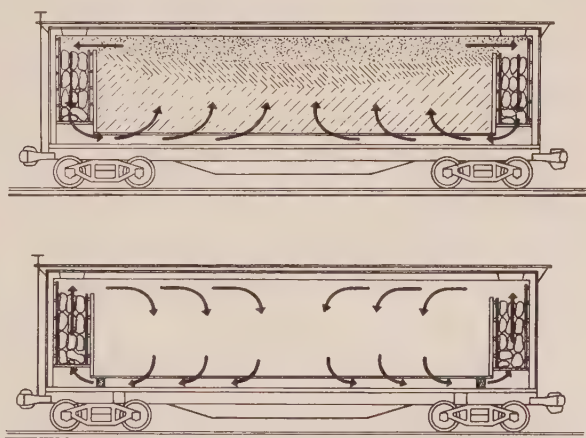


Figure 34. Top: A conventional refrigerator car showing direction of air movement. The tendency for the development of temperature differentials or temperature stratification is indicated by the shading. Bottom: Both the faster rate of air movement and the reversal of air circulation, in cars equipped with fans that are driven from the car wheels, result in uniformly low mean transit temperatures.¹²

Most refrigerator cars have ice bunkers in either end and these are separated from the main portion of the interior by bulkheads. Horizontal openings at the top and bottom of the bulkhead permit air circulation from the ice to the lading. Each ice bunker holds 6000 pounds of ice when iced to full capacity. Over the floor of the car is a set of floor racks that may be tilted to a vertical position to permit cleaning. The floor racks facilitate air circulation through the loaded car.

The two-section doors on either side of the refrigerator car and the plugs at the tops of the ice bunkers are insulated. Hatches located above the plugs

serve to protect the plugs and may also be adjusted to permit ventilation of the load when the plugs are removed.

The usual available space for the lading in a freight refrigerator car is 33 feet, 2 inches (between bulkheads) by 8 feet, 4 inches (width) by 7 feet, 7 inches (height). There are, however, many cars that have slightly different inside dimensions.

Refrigerator car design is undergoing intensive investigation currently and it is possible that changes in bulkhead construction, changes in insulation, and changes in methods of utilizing or providing the refrigeration may also alter the usable inside dimensions of the cars.

Some of the newer cars are equipped with fans located below the bulkheads. These fans are driven from the car wheels when the car is in motion. If the fans are to be operated during stationary pre-cooling, the drive assembly may be disengaged and an electric motor may be employed to drive the fans. These fans reverse the natural direction of air flow in an iced car. The air is drawn from the base of the load of fruit and then moves upward through the ice and out over the load. Thus, the temperature of the fruit in the top layer of fan cars may be slightly lower than that for fruit in the bottom tier of containers. In general, the temperature of the fruit throughout the load of a fan car is maintained at approximately the temperature that is maintained in the bottom tier of containers of a non-fan car.¹²

One kind of fan for permanent installation in cars has a rated air circulation, in terms of cubic feet per minute (c.f.m.), at different train speeds, as follows: 10 m.p.h., 1424 c.f.m.; 25 m.p.h., 3560 c.f.m.; 50 m.p.h., 7120 c.f.m.; and 60 m.p.h., 8504 c.f.m.¹³

Fan cars also provide maximum protection against freezing of the fruit when salt is added to the ice because of the reversed direction of air flow.¹⁴

B. LOADING CARS

It is customary to ice the bunkers of the car about 24 hours before the loading of the fruit is started. This is done to precool the car or extract much of the heat from the car structure and the insulation. Many shippers insist on having a car temperature lower than that of the incoming fruit. Some 200 to 300 pounds of salt often is added to the ice to hasten the rate of cooling of the car. Hukill and Gerhardt¹⁴ found that the greatest effect of the added salt was attained about 18 hours after salting, but that there is no real advantage in salting until shortly before or at the time of loading the fruit.

Boxes of cherries are usually loaded in seven to nine lengthwise rows, the number varying inversely with width of the boxes. There should be vertical and even spacing between rows and between the outer rows and the sidewalls of the car to facilitate air circulation through the load. The number of layers in the load varies with the kind of car, the size of the boxes, and the tonnage of cherries that is to be loaded in the car. Precooled cherries can be loaded to a greater height than those that are not precooled and fan cars can be loaded heavier than those without fans. The tonnage in the average carload of cherries has increased substantially during recent years because of pretransit treatments of the fruit, changes in the refrigerator cars, transit treatments, and carrier concessions.

The boxes in the several tiers of a row extending across the car constitute a stack. Special eight-foot car strips are employed to prevent sidewise shifting of the boxes while in transit. They should be placed over both ends of the boxes in the second or third tier, the top tier, and at least every third intervening tier of a stack. Since the car strips are somewhat shorter than the inside width of a refrigerator car, the ends of alternate strips should extend to one side wall of the car and the ends of the other strips should be against the opposite wall. These strips are nailed to the end pieces of the boxes.¹⁵

The first stack is placed firmly against one of the bulkheads. It is completed before the second stack is started. The ends of the boxes in the second stack must fit tightly against the ends of boxes in the first stack to prevent the accumulation of lengthwise slack in the load. Additional stacks are completed until nearly one-half of the car is loaded (11 stacks in case 15-pound boxes are being loaded). Loading is then started in the opposite end of the car and stack after stack is completed until the space in the doorway area between the stacks is some 18 to 36 inches wide.

This constitutes a divided load. The doorway spacing permits easy access to the load for inspection and permits "squeezing" the load with jacks to take up any lengthwise slack. Another reason for having a divided load is that box and car dimensions are seldom such as would permit the boxes to completely fill the length of the car.

Gates must then be built to fit against the stacks on either side of the space at the doorway. Each gate consists of one vertical board or 2 x 4 for each row of boxes and at least three horizontal cross pieces that extend across the car. After the load is "squeezed", four cross spreaders or stringers are fitted tightly between each of the horizontal cross pieces of the gates to hold the load firmly in place during transit when the car may be subjected to many lengthwise thrusts.¹⁶ Detailed instructions for doorway bracing may be obtained through the agent of the carrier.

Loads of 16,000 to 20,000 pounds of fruit were usual prior to 1933.¹⁷ Current loading for cherries varies from around 27,000 pounds to as much as 34,000 pounds.

C. ICE CONSUMPTION IN TRANSIT

The rate of heat leakage through the walls, roof, and floor of a refrigerated car varies with the design and condition of the car,

the temperature to which it is exposed, and the rate of travel. Hawkins¹⁸ assumed the rate to be about 2 B.t.u. per square foot per day for each degree difference in temperature for cars that presumably had 3 to 3.5 inches of insulation. A surface area of 1414 square feet for a car and an average daily temperature differential of 30°F. between the inside and the outside of the car would then give a daily leakage of 84,840 B.t.u. This would require the melting of 589 pounds of ice per day to counteract the heat leakage through the superficial area of the car.¹⁸ If the average daily temperature differential is 45°F., as it might well be if the load is precooled to a temperature below 35°F., the daily heat leakage would be 127,260 B.t.u., equivalent to the heat absorbed in melting 884 pounds of ice.

The heat evolved by the cherries in the process of respiration must also be counteracted by melting ice. Assuming 30,000 pounds of cherries maintained at a temperature of approximately 40°F., the amount of heat generated during a 24-hour period likely would be 45,000 to 50,000 B.t.u. This would be the equivalent of the heat absorbed by the melting of 313 to 348 pounds of ice.

Assuming a median value for heat of respiration and an outdoor temperature of 80°F., the total number of pounds of ice consumed in a day to maintain a fruit temperature of 40°F., or slightly lower, would be at a rate of approximately 1100 pounds. Obviously, the mean outdoor temperature during a transcontinental trip would be lower than 80°F. and the mean transit temperature of precooled cherries loaded in fan cars would be lower than 40°F.

D. TRANSPORTATION PRACTICES FOR RAILROAD SHIPMENTS

Practically all sweet cherries that move in transcontinental shipments are billed "standard refrigeration". This means that the ice is replenished at all regular icing stations enroute. This may call for as many as ten reicings under freight service for a transcontinental shipment.

The usual practice has been to add enough salt to make what is known as three percent salting for the initial icing and to use as much as three percent salt with the ice added at each reicing station enroute. This means that as much as 180 pounds of salt may be added to each end bunker when the car is iced initially. When fan cars are used the billing may call for the use of less salt.

Dry Ice as a Source of Carbon Dioxide in Transit. During the latter years of the nineteen-thirties, a number of shippers of sweet cherries supplemented standard refrigeration by placing substantial quantities of dry ice in the cars so that carbon dioxide could be supplied to the atmosphere of the car by sublimation during at least a major portion of the transit period. The recommended practice with cars that were available in 1940 consisted of placing a minimum of 800 to 1000 pounds of dry ice at the doorway bracing at the time of loading and then adding some additional dry ice to the end bunkers at frequent intervals enroute. The amount of decay developing in transcontinental shipments for cherries of optimum maturity (dark mahogany color and 22.5% soluble solids) was reduced from 16 to 17% for cars containing no dry ice to about 1% for cars that had high amounts of carbon dioxide present for substantial periods of transit time. Fruit shipped in cars with an atmosphere of carbon dioxide remained brighter in color than that in cars without carbon dioxide.¹⁹

Gas retention studies in 124 carloads of sweet cherries in 1941 showed that 50% of these cars were sufficiently gas-tight to maintain eight percent or more of carbon dioxide in the atmosphere for three days. This level of carbon dioxide was regarded as being only 50% of the retention necessary for the most effective use of the gas. The majority of shippers and receivers thought the practice beneficial as indicated, in part, by the fact that 871 cars of cherries originating in the Pacific Northwest in 1941 were shipped by freight under standard refrigeration supplemented with dry ice.²⁰

The recommended method in 1941 was to place 800 to 1000 pounds of solid carbon dioxide in individually packaged 50- to 60-pound cartons in a crib on the bracing at the doorway and then place 50 additional pounds of naked dry ice on top of the water ice in each end bunker. The latter was broken to facilitate rapid sublimation while the dry ice in the cartons sublimated slowly. The maximum concentration of carbon dioxide was attained in three to six hours after the initial charging. Shipments destined for points east of Chicago required the addition of 100 to 200 pounds of dry ice at St. Paul to maintain satisfactory levels of carbon dioxide.²⁰

In 1942, Smith, Gerhardt, and English¹³ placed approximately 800 pounds of solid carbon dioxide in 75-pound express cartons in a crib on the stringers at the doorway and a 70-pound naked cake of

dry ice on the water ice in each bunker at the time the loading was completed at Yakima, Washington, and then replenished with 200 pounds at Laurel, Montana. This maintained the carbon dioxide content of the atmosphere above 13% for four days in all cars excepting those equipped with fans. Recharging with 200 pounds of dry ice at both Laurel and in the vicinity of Chicago resulted in rapid accumulation of carbon dioxide, the effects of which lasted 24 to 30 hours.

The amount of decay in the top layer of boxes in cars containing the dry ice was 6.2% in contrast to 14.1% decay for the top layer of non-gassed cars. It was also noted that carbon dioxide had a greater effect in preventing decay in fruit of the top layer of boxes of a 34,000-pound load than did fans, despite a 7°F. lower temperature in the latter.

Smith and his associates suggest that a smaller initial charge than was used in these tests and the addition of some dry ice at all reicing stations may be the most satisfactory practice, when standard refrigeration is supplemented with solid carbon dioxide. This report does not indicate that it is advisable to use dry ice in cars that are equipped with fans.

Fan Cars and Salting Practices. The temperatures of precooled cherries in cars to which three percent salt was added with ice at all regular icing stations, was found to increase from the bottom to the top of the load at the rate of about one degree for each layer of boxes. On the other hand, the spread between maximum and minimum temperatures of the commodity that was shipped in fan cars was 3.3°F. Furthermore, the average commodity temperature dropped from approximately 36°F. to 32°F. during transit in the latter cars. The fan cars, however, melted a greater amount of ice and used more salt, when the salt was added on a percentage basis, than did the non-fan cars. The wheel-driven fans were in operation 62% of the time that the cars were enroute. No significant difference was found in weight losses due to transpiration for fruit shipped in the two kinds of cars.¹³

In later experimental shipments, desirable commodity temperatures were maintained in fan cars when the initial salting was at the rate of 1.5% and this was followed by the addition of 70 to 100 pounds of salt with the added ice at each re-icing station enroute. These practices also eliminated the possibility of excessively low commodity temperatures.²¹

A 50-foot overhead basket bunker car must be salted at a rate higher than four percent to provide commodity temperatures equal to those obtained with three percent salting in end bunker cars.²¹

Recommended Transit Practices. It is evident that successful transcontinental shipment of sweet cherries in freight refrigerator cars of the end bunker type is practical in freight service. In all cases, the cherries should be precooled to temperatures below 40°F. and the cars should be preiced to bunker capacity approximately 24 hours prior to loading.

If the cars are not equipped with wheel-driven fans, standard refrigeration with three percent salting after loading and enroute should be supplemented by the placement of 800 to 900 pounds of solid carbon dioxide in express cartons on the stringers of the doorway bracing and some 75 pounds of naked dry ice be placed on the water ice of each end bunker. It appears advisable to add some 200 pounds of dry ice at each of two reicing stations en route.

Cars equipped with fans are currently available for most of the crop that moves in transcontinental shipment. It is not necessary, nor advisable, to use supplementary solid carbon dioxide in such cars. These cars should move under standard refrigeration with an initial salting at a rate of approximately 1.5% and 70 to 100 pounds of salt should be included with the ice added to replenish the bunkers at every reicing station en route.

E. HIGHWAY AND AIR TRANSPORTATION

Most of the cherries grown in the eastern states for the fresh fruit market are transported by truck. The trucks and trailers that transport the cherries substantial distances have insulated bodies and many of them are equipped with mechanical refrigeration. The development of refrigerated transit in trucks has gradually increased the distance to which highly perishable fruits are moved over the highways. Transcontinental movement in trucks of some kinds of fruits is increasing and it may not be long until a substantial portion of the cherries may be shipped in trucks and trailers that are equipped with forced circulation of refrigerated air. The determining factors probably will be the elapsed transit time and the relative costs of refrigerated transportation by rail and by truck.

It is likely that the pre-transit treatments and transit temperatures that apply to rail transportation will apply equally well to long-distance transportation by trucks.

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The sweet cherry has been considered as one of the products suitable for air shipment and this fruit may move in some volume when air freight undergoes further development. This will be particularly true with early season shipments for which time is the essence of price. The cost, however, likely will be considerably higher per ton mile than that for rail shipments and the final selling price, even for the early crop, may not justify the additional cost.²⁰

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PRESERVATION BY CANNING**1. Quantity of Canned Pack**

Cherries are particularly well adapted to preservation by canning. Several generations have witnessed the home canning of both sweet and red cherries and these fruits have long been favorites for such preservation. Commercial canning of cherries in substantial quantities probably began soon after the development of the sanitary can at the beginning of the current century. The first available record shows that approximately 4,800 tons of sweet cherries and 2,200 tons of red cherries were processed in commercial canning plants in the United States in 1909 (Chapter II). These data indicate that commercial canning of these products was rather well established by that time.

Pitted Red Cherries. Red cherries are pitted before they are processed and are therefore known in the trade as pitted red cherries or RSP (red sour pitted) cherries. For the seven reasonably good crop years ending with 1952, the numbers of actual cases packed in the United States ranged from about 2,400,000 in 1947 to slightly in excess of 5,000,000 cases in 1950. The average was 4,117,000 cases. An average of approximately 64,000 tons of raw product was canned during the seven years. About 59% was packed in No. 2 cans, about 39% in No. 10 cans and about 2% in cans of miscellaneous sizes. There appears to be no definite relationship between size of crop and the percentages of the raw product packed in No. 2 or No. 10 cans.¹

Approximately 71% of the actual cases of red cherries packed during the 1946–1952 period were processed in Michigan; New York and Pennsylvania accounted for slightly more than 13% of the cases packed and Wisconsin packed slightly over 10% of the total.

Sweet Cherries. The average number of actual cases of sweet cherries packed for the years 1943 to 1952, inclusive, was nearly 1,300,000. The pack ranged from 643,000 cases in 1947 to 2,082,000

cases in 1946. The percentage distribution for can sizes for the ten years in terms of cases was: No. 2¹/₂ cans, 38% ; No. 2 cans, 18% ; No. 10 cans, 14% ; No. 8Z short and tall, 9% ; No. 1 cans, 4% ; Miscellaneous cans, including No. 303, 17%.¹

An outstanding trend during the 10 years was an increase in number of cases of No. 303 cans packed. This pack increased gradually from around 65,000 cases in 1948 (the first year for which data are available) to approximately 725,000 cases in 1952. The number of cases of No. 2¹/₂ cans packed during the years 1947-1952 was approximately one-half the number packed during the previous five years.¹ Thus, the No. 2¹/₂ can is no longer the predominant one for sweet cherries and the No. 303 can has become the most popular size for outlets through retail stores.

Approximately 56% of the average number of "actual cases" of sweet cherries canned during the period from 1943 to 1952, inclusive, were packed in Oregon and Washington. California contributed approximately 36% of the total pack in terms of numbers of cases. These percentages must be regarded as rough approximations of volume of pack because the proportions of cases of cans of the several sizes were not the same in the different regions.

2. Varieties for Canning

Montmorency, the only variety that is canned in substantial quantities in all regions that grow red cherries, is favored because of the excellent quality, the firmness in flesh, the size of the fruit, the long harvest season, and because it is a dependable producer of good crops.

Early Richmond and English Morello are canned in limited quantities principally because they are earlier and later, respectively, than Montmorency and, therefore, serve to lengthen the packing season. Both varieties are declining in popularity for canning because packers have learned to prolong packing seasons by trucking the more desirable Montmorency from areas that have earlier or later ripening periods than those in which the factories are located.

Napoleon (Royal Ann) is the most important sweet variety for canning; in fact, this variety is grown almost exclusively for canning and other kinds of processing. Among the dark-colored sweet varieties, Bing and Lambert are the most popular. Schmidt and some of the

other firm-fleshed, dark-colored sweets are canned to a limited extent in the north-central and eastern states.

The canning seasons for cherries in the several producing regions are essentially those when the Montmorency and the Napoleon varieties are ready to be harvested. The approximate periods for canning the red cherries and the sweet cherries in an average season in each important region are shown in Figure 35. The important states

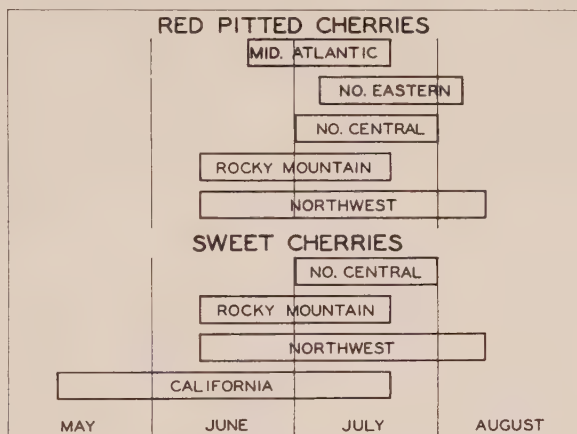


Figure 35. Approximate canning seasons for red pitted and sweet cherries in important regions of production.

in cherry production in each of the regions are as follows: Mid-Atlantic; Pennsylvania; Northeastern: New York; North-Central: Ohio, Michigan, and Wisconsin; Rocky Mountain: Colorado, Utah, Montana, and Southern Idaho; Northwest: Oregon, Washington, and Northern Idaho.

The very long canning seasons shown for the Northwestern states and California are made possible by both differences in latitude and differences in altitude within the areas, rather than by the utilization of different varieties.

3. Maturity in Relation to Canning

Table 21 shows that premature harvest of Napoleon cherries yields a canned product that is soft in texture, somewhat flat in taste,

TABLE 21. INFLUENCE OF MATURITY ON THE QUALITY OF NAPOLEON CHERRIES CANNED IN 40% SYRUP, 1925²

Date of harvest and canning	Balling test of raw juice	Quality ratings March 12					Loss of wt. of fruit, %
		Maturity	Color of juice	Texture of flesh	Flavor	Quality rating	
June 16	12.2	Immature	Clear	Soft	Flat	Poor	12.9
June 19	13.2	Immature	Clear	Soft	Flat	Poor	10.0
June 22	14.1	Immature	Clear	Soft	Flat	Poor	10.5
June 25	16.3	Immature	Clear	Somewhat soft	Flat	Fair	10.4
June 28	18.7	Slightly immature	Clear	Fairly firm	Fairly strong	Fair to good	9.8
July 1	19.9	Ripe	Light pink	Firm	Fairly strong	Good to very good	6.3
July 4	21.0	Ripe	Light pink	Firm	Full flavor	Very good	6.3
July 9	24.1	Very ripe	Light pink	Firm	Full flavor	Very good	6.4

poor in quality rating, and subject to loss of weight or to shriveling. On the other hand, cherries that are fully matured when harvested produce a canned product that is firm in texture, has pronounced cherry flavor and aroma, and is very good quality. The loss of weight in canning ripe fruits was only about one-half that observed for cherries harvested when the Balling test of raw juice was only 12.2%. Cherries that had passed prime condition slightly at the time of harvest gave a canned product that was exceptionally good in quality but the fruits showed more or less "leathering."²

The degree of maturity has a very noticeable effect on the firmness of the canned product. Napoleon cherries harvested over a three-week period and packed in 40% syrup produced canned fruit that increased in firmness from 63.1 grams for the first picking to 94.4 grams for the last picking. The increase in firmness of the canned fruit was even more strikingly associated with maturity when the fruit was canned in water.²

Time of picking affects substantially the solids, sugar, and acid content of the juice in canned cherries. In one test, the juice cut-out (the concentration of soluble solids in the liquid of the can after storage as determined by Balling or Brix readings) of Napoleon cherries packed in 40% syrup ranged from 25.5% for the fruit picked June 4 to 30.9% for that picked three weeks later (Figure 36). Total sugars for the juice ranged from 24.4 to 28.2% for the same lots. Napoleon cherries harvested June 4, and then canned in water, had a juice cut-out of 9.0% and a total sugars content of 5.6% compared with a juice cut-out of 14.3% and a total sugars content of 9.6% for those harvested June 25.² This very close relationship between the solids content of the raw juice and juice cut-outs for both syrup-packed and water-packed cherries is clearly illustrated in Figure 36.

Data for both the total acidity and the hydrogen-ion concentration of the juice of canned cherries show that the acidity is more pronounced for the early picked fruit than for that harvested when it is ripe. Similar trends obtained when the cherries were canned in water.² Apparently, the canning process does not materially affect the original acidity of the fruit.

Data providing the basis for the preceding presentation were for the Napoleon variety. Hartman³ included the Lambert variety in some less extensive tests and obtained similar results. Observations in the canning industry indicate that similar trends prevail following the

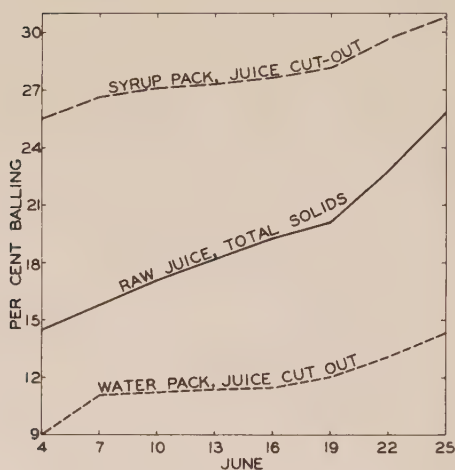


Figure 36. The relation of maturity (time of picking) to juice cut-out in Napoleon cherries canned in water and in 40% syrup.²

canning of immature and mature fruits of other varieties of sweet and red cherries.

4. Preparation for Canning

Red cherries and most sweet cherries that are to be canned are picked without stems to facilitate both harvesting operations and handling in the factory. They are transported from the orchard to the canning factory in shallow lug boxes.

In case sweet cherries are picked with stems, these stems may be removed at the factory by stemmers that have sets of cylindrical rubber rolls, set at a slightly inclined position, that revolve toward each other and thus pull the stems from the fruits. The few stems remaining intact with the fruits after the cherries leave the mechanical stemmer are removed by hand.

A. PLATFORM INSPECTION

The cost of handling cherries in the factory increases directly with the percentage of defective fruits. Not more than five percent defective cherries can be removed from the inspection belts without slowing the speed of the belt or employing more than the usual number of sorters. Even then there is a likelihood that the number of blem-

ished cherries entering the cans may exceed the tolerance permitted for the better grades. It is thus obvious that the canner cannot afford to pay the same price for a raw product that grades out 90% usable fruits as he pays for cherries that have only two or three percent that should be removed from the sorting belts.

Many canners of red pitted cherries pay the established price to all growers whose product grades 95%, or higher, unblemished and otherwise normal fruits. Other growers are paid on a sliding scale determined by the grade attained by the cherries. For example, some canners may discount the price one percent for each point below 95% grade and if the percentage of defective fruits is greater than 10, they may discount as much as 5% for each percentage score below 90. The grade is determined by so-called platform inspectors. These inspectors remove a few cherries from every fourth or fifth lug, mix the sample and sort out the defective, undersized, and immature cherries to determine the percentage grade out.

Many growers find it advantageous to instruct their pickers to drop defective and otherwise undesirable cherries during harvesting operations. It is actually less expensive for the grower to eliminate these cherries than for the packer to do so. Such growers are reasonably certain to avoid dockage for delivering cherries that fail to meet the established standards for cherries that are to be canned.

When maggot infestation is suspected, it is necessary for the platform inspectors to subject the representative sample to the test prescribed for the presence of this pest.

Twelve grower-lots of Montmorency cherries were traced through canning plants to determine the relationship between the quality of the fresh fruit and that of the processed product. These lots showed total defects of fresh cherries ranging from 4.25 to 19.05% and serious defects ranging from 1.75 to 8.87%. (See Chapter XVII for definition of serious defects.) Only one of the lots of fresh cherries graded U.S. No. 1 at the receiving platform. No close relationship was found between total defects of raw product and total major and minor defects in the canned product. Neither was grade designation of the fresh cherries found to be an entirely suitable index of quality of the canned product. On the other hand, a fair degree of relationship was found to exist between the percentages of serious defects affecting processing quality, less the percentages of pick-outs, and the total percentages of major and minor defects of the processed cherries.⁴

The above evidence would seem to indicate the advisability of some change in the basis for both the segregation of loads of cherries as to quality and payment to the grower.

B. WASHING, SOAKING, AND STORING

Dumping and Washing. The cherries should be transferred from the lug boxes in a manner that will reduce bruising of fruits to a minimum. In some cases the cherries are emptied from the lug boxes into hoppers from which they are carried by a belt conveyor equipped with cross pieces to washers or soaking tanks (Figure 37). Some

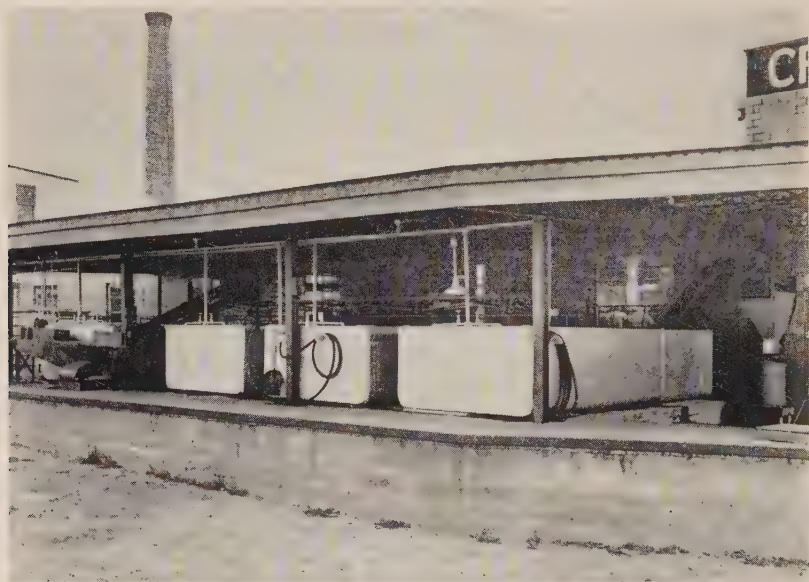


Figure 37. Soaking tanks usually are located in open sheds that adjoin the canning factory or freezing plant. The gooseneck elevator, immediately back of the tank on the right, delivers the cherries to the cross-bar-type eliminator where the undersize fruit drops into a hopper and is collected in a metal barrel. The cherries that pass over the eliminator are delivered to sorting belts inside the factory. (Courtesy of Crystal Canning Co.)

packers empty the lug boxes into water flumes that serve to convey the fruits to washers or soaking tanks. One large operator sets the lug boxes on a motor-driven belt conveyor so constructed that the lug boxes are made to turn on their longitudinal axis gradually, by moving

through a twist, to spill the fruits onto another belt conveyor. It is claimed that this system expedites handling and reduces bruises to a minimum. Still another method is to dump the cherries into a hopper that maintains a relatively high water level from which they are elevated hydraulically through a large tube to water flumes. The method commonly employed in the smaller plants that process red cherries is to dump the cherries directly into tanks of water.

Sweet cherries should be washed thoroughly under a cold water spray or in an immersion-type washer. The washing of red cherries is usually accomplished by soaking for several hours, then fluming in water and, finally, rinsing the cherries under strong sprays of fresh tap water.

Soaking and Storing. The generally accepted practice of soaking red cherries in tanks of cold water for several hours prior to pitting was developed by W. R. Kappler⁵ at Northport, Michigan, in 1918. Kappler was interested in firming the fruits to make possible cleaner pitting and a higher yield of canned cherries per unit of raw product. He found that soaking the cherries in water at approximately room temperature gave no improvement in pitting. Soaking the fruits in a tank in which the water was maintained at well-water temperature through a continuous supply of fresh water gave the improvement in pitting that he was seeking and the practice soon became standard.

The soaking operation, according to Kappler, washes the cherries, removes some spray residue, permits replacement of some of the moisture that may be lost through transpiration between the time of picking and the time of arrival at the canning factory and firms the cherries so that the pitting operation may be performed without excessive tearing of the flesh and with little loss of juice. Kappler's data indicate that a soaking time of 12 to 20 hours supplied continuously with water having a temperature of 46°F. is suitable for Montmorency cherries harvested in an immature condition, but that eight to 16 hours is satisfactory for fully matured cherries. Similar treatments with fruits of the Early Richmond variety indicated that immature fruits should be soaked 16 to 24 hours while eight to 16 hours seemed to be satisfactory for fruits that were properly matured. Drained weight for the canned cherries decreased with increased lengths of soaking time, but the amounts of head space in the cans filled with cherries that had not been soaked or those that had been in the soaking tanks for inadequate periods of time were excessive.

No injurious effects were noted when firm Montmorency cherries were soaked for six to 12 hours in water at 50 to 55°F. Longer soaking resulted in a loss of 12 to 14% for acids and losses of approximately 5 and 10%, respectively, in soluble solids from ripe and under-ripe fruit. Over-ripe fruits that were not soft showed no loss in soluble solids. When the soaking time was increased to 24 hours, the skin of the fruit darkened and marked flavor impairment resulted. The cherries lost weight during the first four or five hours of soaking but gained steadily thereafter. These weight increases amounted to 0.13%, 0.58%, and 1.26%, respectively, for underripe, ripe, and over-ripe cherries during a 12-hour soaking period.⁶

One packer⁷ recommends soaking for six hours in water having a temperature not higher than 50°F. He later reported in correspondence that a soaking time of six to eight hours gave greater drained weights for processed cherries than a soaking time of three to four hours. Swingle⁸ reports that cherries lost as much as 4.4% in weight during a four-hour soaking period but Langer and Fisher⁹ observed no significant changes in weight of fruits when soaked. Griswold¹⁰ observed that canned Montmorency cherries became more orange in color as the soaking time was increased from 0 to 24 hours, but she reports that the water bath temperature was 61°F., which is higher than that employed in commercial plants.

Investigations conducted in Michigan in 1949 indicated that soaking Montmorency cherries in running tap water at 57°F. results in considerable loss of fruit due to cullage, loss of soluble solids, loss of color and increased toughness. It was concluded that soaking for six hours or more is no more effective in preventing excessive losses due to pitting damage and loss of juice than is cooling the cherries in air or by hydrocooling. In other words, one of the principal objectives of cooling appears to be that of temperature reduction of the raw product. Soaking, however, provides a convenient means of cooling and storing large volumes of fresh fruit.¹¹

Subsequent results obtained with cherries soaked for periods ranging from zero to 48 hours in water supplied continuously at 45°F. and 57°F. indicate that water at the lower temperature is more desirable and that the soaking time should be limited to 12 hours or less to prevent excessive cullage, loss of soluble solids and color.¹²

The reasons for some of the conflicting reports on the effects of soaking cherries are made apparent by controlled studies in the

laboratory.^{13,14} Unbruised cherries soaked in water for various lengths of time increased in both weight and firmness and decreased in both soluble solids and acid content. Bruised cherries, however, did not gain significantly in weight and lost substantial quantities of soluble solids and acids. The effects of the bruising were proportional to the degree of bruising. Fruits soaked in water at 34°F. were firmer and lost smaller amounts of soluble solids than did cherries held in water at 50 or 70°F. Cherries cooled in air at 34°F. increased steadily in firmness and in percentage of soluble solids.

Certain other benefits are derived from the soaking operation. The long soaking period loosens any dust and foreign matter that may be on the fruits so that such is readily removed during subsequent fluming and spray washing. Leaves and cherries containing the maggots of the cherry fruit flies float on the surface of the water and may be skimmed off. This skimming must be done, however, before the fruits containing maggots have an opportunity to become water-logged and sink to become admixed with the sound cherries.

Still another function of the soaking practice is that of storage. The tanks provide a cheap and practical method for holding the cherries until they can be processed. Most deliveries to factories are made during the late afternoon and evening, while the processing operations are usually done during the 10 to 18 hours following 7:00 A.M.

Soaking Tanks. The soaking tank is usually constructed of heavy-gauge sheet metal with reinforcing at the corners and top edges. The bottom of a tank is usually in the form of a broad "V" with the middle about six to eight inches lower than the outside edges and the bottom also slopes to the outlet end so that the cherries will flow out readily with the water when the tanks are being emptied. The interior of the tank is coated with a lead-free enamel. The outlet must be rather large and should be equipped with a gate valve. An overflow opening or wier should be made so that the water level may be maintained at about three inches from the top edges of the tank and so as to cause the overflow water to be released at one point. A perforated water pipe, extending nearly the full length of the tank, is usually installed a few inches above the bottom of the tank. This serves to distribute the incoming cold water through the cherries.

The most common size holds six to seven tons of cherries. Such tanks are about 12 feet long, about six to seven feet wide and about four to 4.5 feet high along the sides. Some packers have tanks ranging in capacities from six to 15 tons. The latter are about 10 to 14 feet in length and five to six feet in height. There should be enough tank capacity to accommodate nearly one day's plant capacity for a factory that operates eight to ten hours, or enough tank capacity

to accommodate all cherries received after about 6:00 P.M. for a plant that operates two eight-hour shifts.

Liberal quantities of cold well water should be supplied continuously to the tanks that contain cherries. A tank holding six to seven tons of cherries should be supplied with at least 25 gallons of water per minute. The incoming water should have a temperature of 50°F. or lower. Owners of plants that have access to an abundant supply of water at temperatures below 50°F. have a valuable asset in that they can firm the cherries rapidly and well.

C. GRADING FOR SIZE

After the sweet cherries have been washed, they should be graded for size. Copper vibrating screens having circular openings of various sizes are employed for sizing in the western states. The use of screens having openings of 20/32, 22/32, 23/32, 26/32, and 33/32 inches will yield the size grades established by the Cannerymen's League of California.¹⁵

Some graders remove the large sizes of fruit first by allowing all but the largest size to fall through the first screen; the largest size passes over the end of the first screen, feeding onto a conveyor belt operating at right angles to the direction of flow over the grader. The smaller sizes of fruit are separated successively in similar manner. Other graders are so designed that the small sizes of cherries are removed first and the largest size drops progressively from one screen to the next and finally passes over the screen having the largest openings.¹⁵

Red cherries usually are flumed from the soaking tanks to an elevator-conveyor that operates under a spray of rinse water. The cherries then pass over a grader that eliminates fruit having a diameter of less than the desired one-half inch or five-eighths inch. Some of these graders have an endless belt that is about two feet wide and made of metal cross bars spaced one-half inch or five-eighths inch apart (Figure 38). Another type has sets of diverging coil-spring belts that run parallel with the line of flow of the fruits. Both kinds of graders allow the small fruits to drop through between the cross bars or the coil-spring belts while the cherries large enough for canning are carried over the ends of the graders. The coil-spring belt type permits separation of the eliminated cherries into two size graders if such seems to be desirable.

D. SORTING

Rubber inspection belts are used to move the cherries forward between rows of women sorters. The belts are usually long enough to accommodate at least six sorters along either side, though the actual number of sorters required may vary from six to 16 per belt, depending on the quality of the fruit received at the factory and the length of the belt. Most of the belts are 12 feet in length, but some are 14 and 16 feet long. The sorting belt should travel not more than 20 feet per minute. One 12-foot sorting belt usually will handle 2000 to 3000

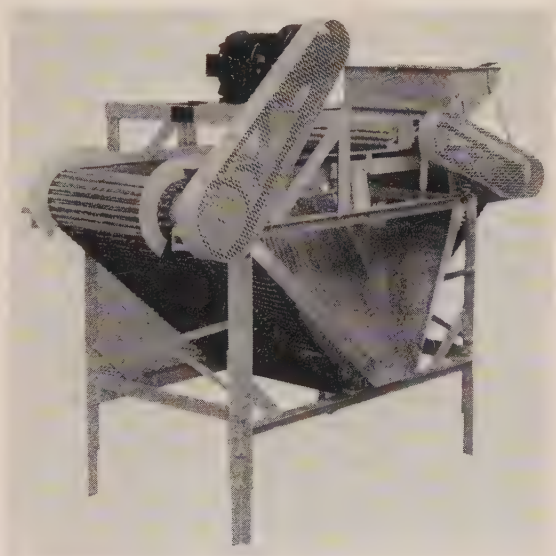


Figure 38. The small cherry eliminator also serves to remove loose pits, mashed cherries, and stems from the fruit before it is delivered to the sorting or picking tables. (Courtesy of Dunkley Company.)

pounds of red cherries of reasonably good quality per hour. At the latter capacity, Montmorency cherries of normal size move past the sorters at the rate of 6,000 per minute. If 5% of these cherries must be discarded to attain the desired grade of canned product, there must be enough women to sort out 300 fruits per minute.

The sorting belts used for red cherries are often located on raised platforms that permit the cherries to move on level belts to the

hoppers that supply the pitters. Obviously, the area over each sorting belt should be well lighted.

The sorters remove fruits that do not have typical cherry color and those that show such blemishes as scar tissue, fungus injury, hail injury, limb rubs, spray injury, insect injury, bruises, and cracks (see grades for cherries in Chapter XVII).

E. PITTING

Most of the sweet cherries are canned without pitting because the retention of the pits adds to the appearance for dessert purposes

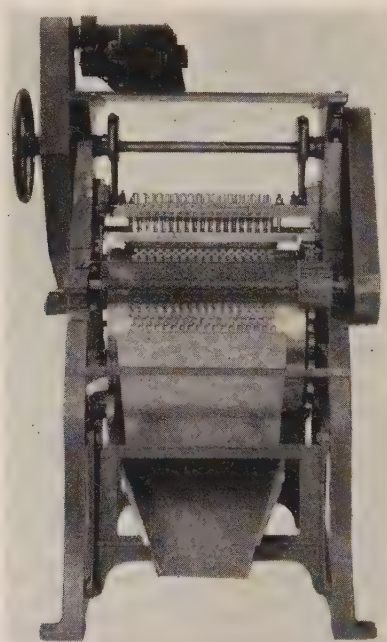


Figure 39. Mechanical pitters are used for pitting both red and sweet cherries. This one has a capacity of one ton of red cherries per hour. (Courtesy of Dunkley Company.)

and imparts a distinctive flavor. However, sweet cherries of the small and medium sizes are pitted prior to canning in some areas. Practically all of the red cherries are pitted. The pitting is done with automatic machines that are remarkably efficient (Figure 39). The cherries are

fed one layer deep onto a revolving cylinder that has rows of cups on its circumference. One fruit falls into each cup and the pits are removed by small cross-shaped plungers that punch the pits through small round holes located in the bottoms of the cups. The pits are usually flumed from the middle of the cylinders and the pitted fruits automatically drop from the cups after the cylinder advances 100 to 120 degrees in its rotation.

Pits constitute 6.5 to 8.5% of the weight of Montmorency fruits. The smallest fruits have the highest percentage of pit weight. There is also some loss of juice during the pitting operation.

The total loss of weight in pitting red cherries seldom exceeds 17%. In fact, the loss from both pick-out on the sorting belt and pitting red cherries of reasonably good quality usually ranges from 17 to 22%. The pits are conveyed to the boiler room where they are used along with coal to supply fuel for the boilers. There is some loss of juice in pitting. Some canners recover this juice and mix it with that expressed from small cherries to make cherry juice.

It is generally assumed that each pitter will handle one ton of red cherries per hour. This usually means that a factory will operate $1\frac{1}{2}$ to 2 pitters for each sorting belt.

In some plants the cherries move directly from the pitters to the can filling equipment but many plants have inspection belts located between the pitters and the filling equipment. Two women usually do the final inspections when such belts are provided. Obviously, such inspection is desirable.

5. Packing

Containers. Red pitted cherries corrode tin plate rapidly and sweet cherries cause some corrosion. The use of special cherry enamel cans has largely eliminated the corrosion problem.

Glass containers occasionally are used as containers for cherries. Their use at present is largely confined to fruits of high quality that are packed in the heavier syrups.

Filling the Cans. The cans for sweet cherries are filled as full as is possible without crushing the fruits when the can covers are applied. The drained weight, however, must be not less than 60% of the weight of water required to fill the can at 68°F., or 17.88 ounces for a No. 2 $\frac{1}{2}$ can.¹⁵ Pitted red cherries must also be packed to

provide certain minimum drained weights after processing. The No. 2 can must yield a drained weight of not less than 13.5 ounces for water pack and $12\frac{3}{4}$ ounces for syrup pack, and the No. 10 can must yield not less than 74 ounces drained weight for water pack and $70\frac{1}{4}$ ounces for syrup pack. The minimum drained weights for red cherries in the No. 303 can are 11 and $10\frac{1}{4}$ ounces, respectively, for water and syrup packs. Since the drained weight of processed cherries obtained from a given unit of pitted raw product varies with the size of fruit, the total solids content, the soaking time and other factors, no specific recommendation can be made regarding fill of the container. The canner must make frequent measurements of the drained weight of his finished product and vary the fill of container accordingly.

The method for determining the drained weight of canned fruits, as prescribed by the Federal Food and Drug Administration, may be found in Chapter XVII.

In general, 15 or more ounces of pitted cherries will be required for a No. 2 can and 85 to 95 ounces for a No. 10 can to provide the minimum drained weights of 13.5 and 74 ounces, respectively, for the finished products packed in water.

The average number of pounds of ungraded red cherries required to pack one dozen No. 10 cans in the Great Lakes Region is approximately 83. Some packers, however, average 78 to 80 pounds per dozen No. 10 cans. If it can be assumed that the average loss in grade-out and pitting amounts to 17%, the average fill for No. 10 cans would be approximately 92 ounces of pitted cherries.

Semi-automatic, "hand-pack" fillers are used in most factories. The filler is essentially a circular, revolving, stainless-steel table in which there are circular holes having the same diameter as the cans that are to be filled. The cherries are delivered to the center of the table by belt conveyor. The cans are fed to the filler automatically and positioned directly beneath each traveling hole in the table. Two women move the cherries outward from the center of the table and through the traveling holes into the cans.¹⁵

The filled cans are delivered by conveyor to the liquid filling machine. It is customary to check the fill of the No. 10 cans, en route to the liquid filling machine, with an under and over weight scale. The fill for No. 2 cans is usually spot-checked by weighing the fill-in for approximately every 100th can.

Relation of Syrup Density to Juice Cut-out. Cherries that are

packed for dessert purposes are canned in syrup and those packed as pie stock are canned in water. Most of the sweet cherries are, therefore, packed in syrup and most of the pitted red cherries are water-packed.

TABLE 22. APPROXIMATE MINIMUM CONCENTRATION OF SYRUP FROM VARIOUS GRADES OF CANNED CHERRIES, IN DEGREES BALLING¹⁵

Variety	Fancy		Choice		Standard		Second		Pie	
	At canning	After storage	At canning	After storage	At canning	After storage	At canning	After storage	At canning	After storage
Black										
Tartarian	40	23	30	20	20	15	10	12	0	10
Napoleon	40	23	30	20	20	15	10	12	0	10

Table 22 shows the syrup concentrations specified by the Canners' League of California for the various grades of sweet cherries and the approximate minimum juice cut-outs that may be expected after canning and storage. The data show that cherries packed with the heavier syrups have lower concentrations of sugar in the syrups after canning than at the time of filling, while fruits packed in 10% syrup or in water have juice cut-outs that are higher in degrees Balling than that of the original liquid. These changes in composition of the syrup are due in part to osmosis.¹⁵

Figure 36 shows that the percentage of total solids in the raw juice influences the juice cut-out substantially. This relationship was found to be constant from year to year, making it possible to predict quite closely what the juice cut-out will be for a given syrup concentration used at canning time and a known Balling test of raw juice of the fruit. Each increase of one percent in sugar content of raw juice (degrees Balling) results in nearly one percent increase in the syrup cut-out.²

Relation of Syrup Concentration to Shriveling and Weight Loss.

A syrup density above 40 degrees Balling is likely to cause unpitted sweet cherries to lose drained weight and to shrivel.¹⁵ On the other hand sweet cherries canned in water may gain a small amount of weight and volume. Hartman and Bullis² say that there is a direct relationship between the concentration of the original syrup and the loss in both weight and volume of fruit, and that this relationship is

due to increased osmotic pressures that accompany increases in concentration of the syrup.

Relation of Syrup Concentration to Quality. Only cherries that are canned in 40-degree syrup may be designated as fancy grade by the Canners' League of California.¹⁵ This is indicative of the relationship between syrup concentrations and quality and palatability.

Griswold¹⁰ reports that Montmorency cherries packed in water compared unfavorably with those packed in 50% syrup in respect to palatability, brightness of color, and texture. The sugar seems to have prevented loss of color during processing but it appears to have had little effect on color during subsequent storage. The water-pack cherries were more yellowish in color than those packed in syrup. She also reports that 40 and 45% sugar syrups gave better palatability scores than were obtained with water-pack cherries.

Even the addition of 0.5–1.0 ounce of sugar to each No. 2 can of Montmorency cherries increased the firmness and brightness substantially and improved the palability over cherries packed in water.¹²

Sucrose vs. Sucrose-Dextrose Syrup. Van Arsdale and Eddy¹⁶ found that equal parts of sucrose and dextrose make an acceptable syrup for canning cherries but that a syrup made from three parts of dextrose to one part of sucrose gave a canned product that was not acceptable. Fellers et al.¹⁷ canned Montmorency cherries in 60% syrups and reported that those packed in the two parts sucrose and one part dextrose were acceptable while those in three parts sucrose and one part dextrose were preferred to all sucrose. Griswold¹⁰ found that dextrose gave a product having a weaker color and a poorer quality score than sucrose.

Temperature of Syrup and Water. All syrup and water added to the cans of sweet cherries should be boiled thoroughly to remove oxygen. The syrup may then be cooled, without agitation, to about 120°F. The addition of very hot syrup may cause considerable shriveling and splitting of some fruit. Water or syrup should be at or near the boiling point when it is added to pitted red cherries.¹⁸

6. Processing

Exhausting. The objectives in exhausting are as follows: (1) to remove air from the contents of the can and thereby reduce corrosion of tin plate, which is favored by the presence of oxygen; (2) to

produce a vacuum in the can so that the can ends will be concave, and (3) to prevent undue strain on the can when it is subjected to higher temperatures during sterilization. Cans of the smaller sizes may be exhausted to a greater extent than the larger No. 10 cans without resulting in paneling of the side of the containers.¹⁹

Cherries are usually exhausted in hot water. A very simple exhaust that is used in some factories consists in feeding the open cans of syrup-packed or water-packed cherries onto a wide metal belt that conveys the cans through a shallow tank of hot water for the desired length of time. Another type of exhauster conveys the cans in single file back and forth through parallel lanes of a shallow tank that contains water heated by steam pipes. This latter provides for more agitation of the heating medium and therefore raises the temperature of the product somewhat faster than the former. Either type of exhaust boxes are economical in the use of heat and result in little moisture being released to the atmosphere in the factory.

Recommendations vary for both the time and the temperature requirements for exhausting sweet cherries. A can manufacturer recommends exhausting in hot water at 190°F. to a can center temperature of 170°F.¹⁹ Bohart²⁰ recommends exhausting to provide a vacuum of 15 inches in the final product. Cruess¹⁵ suggests at least 10 minutes for the exhaust time and a temperature of 165 to 185°F. Another recommendation for No. 2½ cans is 195 to 200°F. for 6 to 7 minutes.²¹ On the other hand, some canners employ closing temperatures that may be slightly lower than the minima recommended by the investigators cited in this paragraph.

Pitted red cherries should be exhausted sufficiently long to bring the temperature at the center of No. 2 cans to 170°F. and that for No. 10 cans to 160°F. according to one source;²² to 160 to 165°F. as stated in another recommendation;¹⁹ to 180°F. according to still another authority.²³ Some canners use closing temperatures slightly below 160°F. for No. 10 cans to avoid excessive paneling of the cans. The exhaust time is usually about 10 minutes in a water bath maintained at 190 to 200°F.

Sealing the Tin Container. The tin cans are conveyed directly from a railway car or from the can storage by automatic runways to can washers that remove any dust or foreign material that the cans may contain. The cans then continue their progress in the runways to the filling machines and thence through the exhaust to the sealing or closing machines.

Automatic closing machines are so designed that the filled cans are supplied by an automatic timing device. The covers or ends of the cans are then positioned on each open can containing the cherries. The machine then seals the can by making what is known as the double seam. A sealing compound in the curl of the can cover supplies the material that insures a permanent, hermetic seal between the layers of metal when they are rolled together under substantial pressure by the units of the can sealer.

Cooking or Heat Processing. Both sweet and red cherries should be processed in retorts or in continuous, agitating cookers long enough to provide a temperature at the center of the can that is not less than 200°F. Water-pack cherries in No. 2 and No. 2¹/₂ cans usually require 12 to 15 minutes in water at 212°F. and No. 10 cans require 20 to 30 minutes.^{15,19,22,23} When packed in syrup, the time should be increased by as much as five minutes for each 15 degrees increase in Brix of the added syrup.²² One recommendation for water-pack cherries that have an initial product temperature of 160°F. is 12 minutes for No. 2 cans, 15 minutes for No. 2¹/₂ cans, and 20 minutes for No. 10 cans, and for syrup-pack cherries that have an initial temperature of 160°F. the recommended times are 17 minutes for No. 2 and No. 2¹/₂ cans and 35 minutes for No. 10 cans.¹⁹ The foregoing suggestions are for processing in retorts. The time may be reduced substantially when it is done in the continuous rotary cookers. For instance, Campbell²³ suggests 14 minutes for red cherries packed in water in No. 10 cans, and Atkinson and Strachan²¹ recommended 16 minutes in an agitating cooker for No. 2¹/₂ cans and 25 to 30 minutes for No. 10 cans of sweet cherries. One large packer cooks red cherries in a continuous cooker 8 and 14 minutes, respectively, for No. 2 and No. 10 cans.

It is apparent that no specific minimum time can be given that will be satisfactory for a variety of conditions. Temperatures of the product at the center of the can should be determined at the end of the cooking and the processing time increased or decreased to provide a reading of 200°F.

Cooling, Labeling and Casing. The cans and their products should be cooled promptly to about 100°F. after the processing has been completed. Cans that are processed in retorts may be cooled by passing the crates or cages containing the cans through tanks or canals of water in which the flow of the water is in a direction counter to

that of the direction of movement of the cages of cans. Sprays of cold water may also be employed to cool the cans. Where the product is processed in continuous agitator cookers, the cooling may be accomplished in equipment of similar design.

Labels are usually applied by automatic machines that apply the adhesive to one end of the label and then roll the label onto the can at a high rate of speed. The labeled cans are then packed in corrugated fiberboard boxes or cases. Mechanical casers are frequently used for the smaller cans in the larger plants but most factories pack the larger No. 10 cans by hand since only six of the latter cans are packed in a case.

7. By-Products and Factory Wastes

Utilization of Pits. Pits are utilized to furnish a substantial portion of the heat for the boilers in most plants that pack red cherries. They are conveyed to the boiler room where water is allowed to drain from them for a short while and they are then fed into the boiler with some coal. It is undesirable to allow the pits to dry before feeding them to the furnace because dry pits burn too rapidly.

The kernels of the pits may be utilized for the manufacture of fixed oil and bitter almond oil. Preliminary procedures for extracting the kernels from the pits, and extracting and refining the oils are described by Cruess.¹⁵

The pits are crushed between heavy iron rollers that are so adjusted as to break the pits without crushing the kernels. Both shells and kernels are dropped into a tank of brine of such concentration as will allow the shells to sink but will float the kernels. The latter are then skimmed off and sprayed to remove the brine. The kernels are then dried and cleaned with a fanning mill to remove shriveled kernels and other refuse. Sorting to remove pieces of shell, moldy kernels, and foreign material is the next step. The yield of kernels is about 28%.

Fixed oil, the most valuable constituent of the pits, usually is recovered by pressing. The pits are ground coarsely, heated to near the boiling point of water with steam, and then pressed by a continuous press known as an "expeller" or by a hydraulic press that will provide a pressure of three to five tons per square inch. The kernels yield about 30% oil. The subsequent refining may be done at the extraction plant or by the purchaser of the crude oil. The refined oil is used in the preparation of face creams and pharmaceuticals or as a table oil. The principal constituent is olein, $C_{55}H_{105}(C_{17}H_{33}CO_2)_2$, though there are also small amounts of stearin and palmitin.

The press cakes contain the bitter principle called amygdalin and an enzyme called emulsin. The latter has the power to convert amygdalin to benzaldehyde, glucose, and hydrocyanic acid. Benzaldehyde imparts the characteristic odor and flavor to bitter almond oil and to such extracts as "wild cherry." The bitter almond oil is obtained through hydrolysis of the press cake and subsequent distillation. A yield of 0.95% bitter almond oil from the press cake has been reported.

After the bitter almond oil has been recovered, the remaining press cake may be used for stock food. After pressing to free it from water, it has been found to contain 30.87% protein, 42.13% nitrogen-free extract, 8.9% crude fiber, and 13.1% ether extract.

Factory Wastes. The waste from a factory that cans pitted red cherries amounts to 700 to 1,800 gallons per ton of raw product handled. This waste is acid in reaction and contains 700 to 2,100 p.p.m. B.O.D. (biological oxygen demand). Since the pitter juice is the most concentrated, plants should collect and dispose of it separately. The solids contained in the waste water can be coagulated with lime or with ferrous sulfate sufficiently to decrease pollution to the point where the effluent can be handled by municipal treating plants.²⁴

The juice that results from the pitting operation may be collected and utilized in any one of several ways. It may be heated and filtered and then added to the syrup used in canning, it may be added to the juice expressed from small cherries to make cherry juice, it may be used for the manufacture of vinegar, or it may be used in the manufacture of jelly. Some of these practices are of questionable value, however, because pitter juice is diluted with surface water from the fruits. Any such uses are subject to regulations of the Federal Food and Drug Administration.

8. Composition of Canned Cherries

Data showing the analyses for canned cherries should be examined carefully before it is used for comparison with other fruits or even other data for cherries. Most of the sweet cherries are canned with the pits while practically all of the red cherries are pitted. Since the pits in canned sweet cherries amount to about four percent of the total weight of the canned product²⁵ and since they have a relatively high percentage of solids, only the edible portions of the sweet cherry pack may be compared with the canned pitted red cherries. Furthermore, the concentration of the syrup used in packing the cherries

affects the analyses. Unfortunately, the concentration of the initial syrup is seldom stated in available tables.

Solids. Table 23 lists the total solids content for black sweet

TABLE 23. PROXIMATE COMPOSITION OF SOME CANNED CHERRIES, IN PERCENT-AGE¹⁹

Description ^a	No. of Analyses	Total solids	Ash	Fat (E.E.)	Protein (N $\times$ 6.25)	Crude fiber	Carbo-hydrates by difference	Calories per 100 g.
Black, EP, WP	1	19.0	0.4	0.8	0.7	0.2	16.9	78
Black, JP	1	18.9	0.5	0.1	0.5	0.1	17.7	74
Napoleon, WP	2	12.3	0.3	0.3	0.6	0.2	10.8	48
Napoleon, JP	2	16.4	0.6	0.1	0.9	0.2	14.6	63
Napoleon, EP, SP	?	21.9	0.4	0.1	0.6	0.2	20.6	86
Red, pitted, WP	5	13.2	0.4	0.3	0.8	0.1	11.5	50
Red, pitted, JP	2	14.2	0.5	0.9	0.9	0.2	11.8	59
Red, pitted, SP	?	29.8	0.6	0.1	0.6	0.2	28.3	117

^a The letters are to be interpreted as follows: EP, edible portion; WP, water pack; JP, juice pack; SP, syrup pack.

cherries of an unknown variety, Napoleon cherries, and pitted red cherries (probably Montmorency), packed in water, in juice, and in syrups of undesignated concentrations. In some cases, the data are averages of determinations made in different laboratories and in some cases they represent only one set of analyses. Although not stated in several cases, it appears that most, if not all, of the analyses are for the edible portions of the contents of the cans.

The percentage of solids for the dark-colored sweet cherries is higher than that for apparently comparable light-colored sweet cherries. Both kinds of sweet cherries show higher percentages of total solids for water-pack and juice-pack sweet cherries than are presented for pitted red cherries in similar liquids.

Carbohydrates. The carbohydrate content of canned cherries varies with the species and the variety that is packed, with the maturity of the fruit at the time it is harvested, with the concentration of the liquid in which the fruit is packed, and with the presence or absence of pits. Thus, tables of analyses that simply list "canned cherries" are of little value in providing useful data.

Table 23 shows that a positive correlation between total solids and carbohydrate content increases with increases in concentration of the original liquid in which the cherries were packed.

The sugar content of the edible portion of red and white cherries (probably Napoleon) packed in water is reported to be 6.7%.²⁵ Thus, about 70% of the carbohydrate content was sugar. When the same kind of cherries was packed in juice, the sugar content was 11.3%, or approximately 90% of the total carbohydrate content. Obviously, the sugar content increases in syrup packs in proportion to the concentration of syrup.

The fiber content of canned cherries appears to be consistently around 0.2% for the different varieties packed in liquids of varied concentration.²⁵

Acidity. Bridges²⁶ reports a range of 3.82 to 3.93 for the hydrogen-ion concentration of canned black cherries and 3.25 to 3.32 for red cherries packed in water. The concentration of the syrup in which the black cherries were packed is not indicated in the report. A Michigan packer reports that the hydrogen-ion concentration for canned red cherries has run from 3.05 to 3.36; the higher value was obtained for cherries packed late in the season. Values reported by Hartman and Bullis² for cherries packed in 40% syrup were 0.344% total acidity, calculated as malic, and a pH of 3.92 compared to a total acidity of 0.367% and a pH of 3.97 for water-pack. They also found acidity to be more pronounced in fruit that was canned in an immature condition than in that canned when fully mature and conclude that canning apparently does not affect the original acidity of the fruit.

Protein. The limited number of protein determinations ($N \times 6.25$) for the edible portions of canned cherries reported in Table 23 show averages ranging from 0.5 to 0.9%, although there were some individual samples of Napoleon and pitted red cherries that ran as high as 1.0% protein. The table includes analyses reported by Chatfield and Adams²⁵ that range from 0.6 to 0.8% for sweet cherries and show 0.6% protein for pitted red cherries.

Fat. The fat content of the edible portions of canned cherries, as indicated by the ether extract, seems to range from a trace to 1.0% in extreme cases (Table 23). The limited number of analyses and the variable fat contents reported make any differences shown of questionable significance.

Ash and Mineral Content. Table 23 shows that the ash content of the edible portions of canned cherries ranges from 0.3 to 0.6%. There is no indication that differences are due to either the variety of raw product or to the concentration of the syrup employed in the packing.

The mineral components, estimated in milligrams per 100 grams of edible substance, reported for "canned cherries" are as follows: calcium, 11 to 16;^{2,26,27} phosphorus, 12;^{19,26} iron, 1.20 to 2.80;^{19,26} magnesium, 0.5.²⁷ Mineral constituents for canned Napoleon cherries, in terms of milligrams per 100 grams of edible substance, have been observed as follows: Calcium, 59; phosphorus, 17; iron, 0.27; copper, 0.12; manganese, 0.78.²⁵

Caloric Value. Average values of 50 to 117 calories per 100 grams of edible portion of canned cherries are indicated in Table 23. The concentration of the syrup employed in packing the cherries is the most important single factor influencing caloric values. This is obvious because sugar has a high caloric value. The limited amount of evidence indicates that the dark-colored varieties of sweet cherries have higher caloric values after canning than do either the light-colored sweet cherries or the red cherries.

Vitamin Content. The ascorbic acid (vitamin C) content of canned cherries appears to range from about two-thirds to more than 90% of that found in fresh cherries (see Chapter VIII).²⁷⁻²⁹ There is apparently no appreciable change in the carotene (pro-vitamin A) content on canning.²⁸ The thiamine (vitamin B₁) content of canned, pitted red cherries was found to range between 0.024 and 0.028 mg. per 100 g.,²⁸ which indicates a substantial reduction during processing, but the sources of the data for the fresh cherries are different (Chapter VIII). Data assembled for other vitamins in terms of milligrams per 100 grams of canned cherries follow: riboflavin (vitamin B₂), 0.014 to 0.020; niacin, 0.17 to 0.21; pantothenic acid, 0.02 to 0.22.¹⁹ Thus, the niacin content appears to increase when the cherries are canned, but the analyses available are not strictly comparable because the assays were made by different workers and there may be different varieties involved in the different analyses.

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PRESERVATION BY FREEZING

The pitted red cherry is one of the most satisfactory fruits for freezing. It is used largely by bakeries, hotels, restaurants, and caterers that can use substantial withdrawals from low temperature storages. The chief advantages mentioned for frozen cherries compared with canned cherries by 25 firms that handled or used both frozen and canned fruits are: (1) the more attractive appearance due to better retention of the natural fresh-fruit color; (2) the possession of superior flavor; (3) the better support for the pie crust, and therefore fewer cherries required to make an attractive pie; (4) the economy and convenience in handling; and (5) the greater immunity from loss of flavor, color, and appearance.¹

The advantages just listed for frozen cherries are not subscribed to by all commercial users of pitted red cherries. Some bakers prefer the flavor of the canned product. The fact that large quantities of pitted red cherries are hot-processed in cans of institutional size shows that pie bakers are not in complete agreement regarding the relative merits of canned and frozen red cherries.

The light-colored Napoleon cherries that are preserved by freezing are used in salads or as desserts, though some of these sweet cherries are also used by pie bakers. The dark-colored varieties of sweet cherries are in greater demand than the light-colored ones because they retain the natural appearance better when defrosted. These dark sweet cherries are used for dessert and salad purposes and some are sold to pie makers, candy makers, and wine manufacturers.¹

1. Pack Statistics

Red Cherry Packs. Some fresh red cherries were frozen in crates for bakers prior to 1920. There seems to be no record of the first pack of pitted red cherries in barrels. Less than 1,000 barrels were

packed in 1920¹ and some pitted fruit was packed in barrels, without sugar, 1921.² These reports indicate that freezing on a commercial scale began about, or soon after, 1920.

Several packers in the principal areas of production were soon packing pitted cherries in paraffin-lined barrels. It is reported that 8,400 tons were preserved by freezing in 1926 and that the pack in 1930 amounted to slightly more than 18,500 tons. The pack for the latter year was excessive as indicated by the fact that some of the cherries frozen in 1930 were still in warehouses the summer of 1932. The average annual pack for the nine years beginning with the season of 1926 was 7,250 tons. This amount represented approximately 21% of the total quantity of red cherries processed by canning and freezing.³

The average annual packs for Michigan, New York, Wisconsin, and Ohio by five-year periods were: 1932-1936, 6,550 tons; 1937-1941, 14,950 tons, and 1942-46, 18,750 tons. These quantities represented 17, 29, and 36%, respectively, of the total quantities of red cherries processed by canning and freezing in these four states. The average annual rate of increase in the volume of frozen pack for the 15-year period was 1,300 tons for the four states.⁴

Accurate statistics for the frozen packs of pitted red cherries for the United States are available for 1942 and succeeding years.⁵ The total pack ranged from approximately 8,000 tons in 1945 and 11,500 tons in 1943 (poor crop years) to more than 52,200 tons in 1950. The average pack for the years 1942 to 1953 was approximately 32,500 tons and the average for the last five of these years was about 42,450 tons. The average annual rate of increase in pack for the 11 years exceeded 2,900 tons. The evidence, however, indicates that the volume of pack will not continue to increase at these rates; in fact, the pack data for 1949 to 1952, inclusive, might be interpreted as indicating a level plateau had been attained.

Pitted red cherries for freezing were packed exclusively in 50-gallon paraffin-coated fir barrels, that hold about 450 pounds of cherries and sugar, during the first five to seven years of the nineteen twenties. Some small barrels or kegs were used. Most of these were rated at 125 pounds of cherries and sugar. The 30-pound tin can came into usage for pitted red cherries in 1928.¹ Some tin cans holding 15 and 10 pounds were first used in the same year. The 50-pound tin can was introduced in 1929 but was not popular until about 1936. A 40-pound tin can was introduced about the same time but never attained

importance as a container for cherries. These cans have an inner lining of special cherry enamel and have friction tops. Cellophane- or parchment-lined fiber board containers came into usage during World War II when there was a pronounced shortage of available tin plate. They are not as rigid and sturdy nor as air-tight or moisture resistant as are the tin cans and their popularity declined rapidly.

The 50-gallon barrel persisted as a container for frozen red cherries through more than a quarter of a century. Its popularity began to decline rapidly following World War II. Less than one percent of the average pack for the years 1950 to 1952 was in barrels.

The 30-pound tin container is the most popular for institutional use. Approximately 95% of the average pack for 1950 to 1952, inclusive, was placed in containers holding 30 pounds. The 50-pound container reached peak usage in 1944. It has been used for only a small percentage of the pack since the end of World War II made tin plate more readily available.

Little progress has been made in developing market outlets for pitted red cherries in packing containers of consumer size.

Sweet Cherry Packs. Frozen sweet cherries have never been as popular as the canned product, but there is some indication that substantial quantities may be preserved by freezing in the near future.

Nelson and Sulerud¹ state that a limited quantity of Napoleon cherries was frozen in 1927 and 1928 and that nearly 700 barrels were packed in 1930. They indicate that the freezing of dark-colored varieties of sweets began in a limited way in 1926. Their data for the packs of the Pacific Northwest for the years 1926 to 1931, inclusive, show that the quantity of all sweet varieties frozen did not exceed 170 tons in any one season.

An increasing interest in the freezing of sweet cherries began in 1943 and reached a peak of about 5,150 tons for the United States in 1945. The latter year was one in which there were few red cherries available for processing. This was followed by a rather precipitous downward trend, followed, in turn, by packs exceeding 1,100 tons in both 1951 and 1952. The average for the 11-year period ending with 1952 was slightly more than 2,700 tons.⁵

In 1946, nearly one-half of the frozen sweet cherries were in containers holding one pound or less. In subsequent years the trend has been decidedly in the direction of packs designed for institutional rather than retail outlets. For the years 1950 to 1952, inclusive, ap-

proximately 45% of the tonnage of frozen sweet cherries was in 30-pound containers and 37% in barrels.⁵

2. Varieties for Freezing

Montmorency is the leading variety of cherries for freezing preservation. The frozen product of this variety is excellent and it is in great demand by pie bakers. Among the other red varieties, English Morello is considered good, but early Richmond is too watery, too poor in texture, and too poorly flavored to make a satisfactory frozen product. Royal Duke and May Duke are excellent when frozen and Reine Hortense rates good.⁶ There are, however, relatively small quantities of these Duke varieties available for freezing.

Opinions differ as to the quality of frozen sweet cherries. They are likely to oxidize during freezing and especially during thawing. The light-colored varieties are more subject to oxidation than the dark-colored varieties. Oxidation causes the cherries to turn brown or even black.

Napoleon, Bing, Lambert, Black Republican, and Black Tartarian are regarded as suitable for freezing. The dark-colored varieties of sweet cherries are rated much superior to Napoleon for this method of preparation.⁷ Schmidt seems to be the leading variety of sweet cherries for freezing in the midwestern and eastern states. Windsor and other firm-fleshed varieties of sweet cherries are frozen to a limited extent in these areas.

3. Preparation of Cherries for Freezing

A. PREPACKING TREATMENTS

The methods employed for handling cherries, especially red cherries, prior to the time they are packaged for freezing are similar to those described in the preceding chapter for cherries that are to be canned. Many processors used the same lines for preparing cherries for canning and freezing—in fact, they may change from one method of processing to the other more than once during the same day. Thus, a freezer of cherries must have essentially the same equipment for handling prior to packing as does the canner.

Some packers of frozen red cherries use a grader that eliminates all fruit smaller than five-eighths inches rather than the one-half inch

elimination that is usually employed for preparing cherries for canning.

Sweet cherries that are to be supplied to brokers and processors usually are pitted and pitting is a most acceptable prepacking treatment for sweet cherries that are to be frozen for dessert use. Both steam blanching and lye dipping were found to check the skins of unpitted cherries and thus facilitate penetration of sugar. Suitable sugar penetration in the raw, whole, frozen sweet cherry, however, is practically impossible. Thus, pitting of sweet cherries that are to be frozen is common practice in commercial plants since the practice assures sugar penetration without destruction of desirable color and flavor.⁷

While careful and rapid handling of the cherries is of utmost importance for fruit that is to be canned, it is of even greater importance for cherries that are to be frozen. Bruises and cherries that are broken up by faulty pitting are readily detected in the frozen pack. Pitting of the cherries aggravates the oxidation problem and thus makes it essential that the time from initial factory handling to freezing should be reduced to a minimum.

B. DRY SUGAR VS. SYRUP

Dry sugar or sugar syrup is added to cherries at the time the fruit is packed to help preserve color, flavor, and texture. Dry sugar usually is employed when containers holding 30 pounds or more are packed, and it is also used in the packing of even smaller containers of red cherries.

Most packers believe that the use of dry sugar makes possible a maximum drained weight on defrosting. Tressler and DuBois⁸ support this contention but Loutfi *et al.*⁹ found that similar drained weights were obtained when Montmorency cherries were packed in dry sugar or in syrup of 50 to 60° Brix.

When dry sugar is used, it is added to the pitted cherries in such amounts as will provide one part of sugar to each four to five parts of fruit by weight. When the ratio of fruit to sugar is five to one, the pack is designated as 5 + 1 by the packers and distributors. Since the higher concentrations of sugar result in lower drained weights when defrosted, the 5 + 1 pack is preferred by most packers.

The pitted cherries may be mixed with dry sugar in a mechanical tumbler-type mixer. Such a practice is employed frequently when sweet cherries are packed. The sugar usually is added to pitted red cherries at the time the containers are being filled. This method is discussed under a subsequent heading.

Cherries that are frozen for use as desserts and those packed in containers of consumer size are generally packed with sugar in the form of syrup. The advantages for the use of syrup have been set forth as follows: (1) air discoloration is reduced to a minimum; (2) syrup is more convenient to use; (3) the addition of syrup causes less damage to the fruit than does the addition of dry sugar; (4) a more uniform and more attractive pack is obtained; (5) syrup may be chilled before use and therefore act as a precooling agent; and (6) the texture of the thawed fruit is better.⁷

Very high concentrations of syrup may cause shrinkage and toughening of tissues, may extract some of the color and flavor from cherries, and may cause some of the fruit to float. Diehl *et al.*¹⁰ recommend a syrup of 60 to 65° Brix for sweet cherries. Joslyn and Hohl⁷ state that a syrup of 65° Brix results in an excessively sweet pack. They say that packers seldom use a syrup of more than 40° Brix for sweet cherries and that 50% is satisfactory for red cherries.

Carrick¹¹ found that the addition of the sugar in the form of syrup to cherries invariably gave a product having a better color than that obtained from the addition of either standard granulated or fine granulated sugar in the dry state.

Substitution of dextrose or honey for cane or beet sugar may result in objectionable flavors and discoloration of the fruit. Dextrose also may crystallize out on freezing, leaving the fruit covered with unattractive, soft, white crystals. Commercial glucose syrups are superior to dextrose in color retention but they impart a slightly objectionable flavor to the fruit. Mixtures of high conversion corn syrup with cane sugar in a one-to-three ratio have been found to be equal to cane sugar.⁷

Cruess *et al.*¹² packed unpitted and pitted Bing sweet cherries with sugar syrups of densities that ranged from 60 to 20° Brix, so as to provide an average fruit-syrup ratio of approximately 1 : 1. No relationship was observed between syrup densities and drained weights at the end of two weeks' storage at 0° F. and sugar density had no significant effect on the hydrogen-ion concentrations of the syrup as measured after thawing.

The investigators observed that there was better penetration of syrup sugar into the pitted fruit, as indicated by the soluble solids content, especially that packed in 60, 50, and 40° syrups, than occurred for the unpitted fruit. This was due to increased surface areas of un-

pitted fruit in contact with the syrup and the direct contact of the syrup with the flesh of the pitted cavities. Differences were not so consistent for 30 and 20° syrups since sugar penetration was relatively slight at the syrup densities for both unpitted and pitted fruits. The flavor of the cherries packed with syrup at the two lowest densities employed was essentially that of unsweetened fruit.

C. ANTIOXIDANTS

Sweet cherries are likely to darken quickly due to the presence of oxidative enzymes. The browning is caused principally by the interaction of an oxidative enzyme with molecular oxygen and a suitable color base. Low temperatures retard enzymatic activity but they do not prevent it. Exclusion of air by immersion of the cherries in a syrup aids in limiting the amount of darkening. Sugar also acts as an enzyme inhibitor.¹²

There seems to be conflicting evidence as to whether the above methods of inhibiting oxidation of unpitted sweet cherries and pitted red cherries are ample but there is general agreement among investigators that antioxidant agents, such as ascorbic acid, should be used to prevent browning of pitted sweet cherries. Joslyn and Hohl⁷ suggest the use of ascorbic acid for pitted Napoleon cherries at the rate of 0.25% by weight dissolved in 40° Brix syrup. Enough of this syrup should be added to the container to cover the fruit. Bedford¹³ found that the addition of 200 to 250 mg. of ascorbic acid per pound of fruit in syrup inhibited oxidation in pitted Bing and Lambert cherries.

Winter¹⁴ found that 200 to 250 mg. of ascorbic acid per pound of fruit and syrup plus the addition of a small amount of citric acid made frozen sweet cherries acceptable. Strachan and Moyls¹⁵ report all lots of unpitted sweet cherries packed by them were unsatisfactory because of an undesirable oxidized flavor, unless antioxidants were used. The addition of 355 to 367 mg. of citric acid and 175 to 250 mg. of ascorbic acid to each 15 ounces of fruit and syrup markedly enhanced the flavor and color of pitted Napoleon, Bing and Lambert cherries. The retention of the ascorbic acid after a storage period of 10 months at -4°F. amounted to 75 to 89% of the original content for Lambert and retention was similar for two varieties.

Antioxidants are not used by commercial packers of pitted red cherries and it has been stated that there is no advantage in adding ascorbic acid.⁷ However, Loutfi *et al.*⁹ report that the use of 150 mg. per pound of fruit and syrup in syrup packs and 175 mg. in dry sugar

packs maintained fresh flavor and prevented browning of Montmorency cherries. Color ratings were in the following descending order: syrup plus ascorbic acid, dry sugar plus ascorbic acid, syrup, dry sugar.

D. FILLING CONTAINERS

A 50-gallon barrel will accommodate 450 pounds of pitted cherries and sugar. Thus, a 5 + 1 pack calls for 375 pounds of pitted

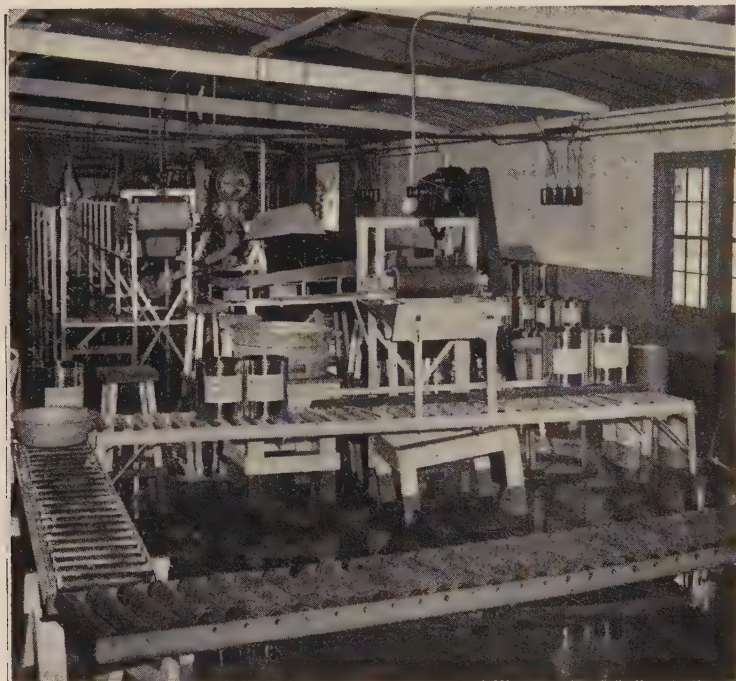


Figure 40. Interior of a four-pitter size plant that is used to prepare red cherries for freezing. Note belt at upper left that supplies cherries to the pitters. A portion of the belt that conveys the pitted cherries to the filling hopper is used for a second inspection. The 30-pound friction-top containers are filled from the hopper at the end of the belt and sugar is added as the containers pass by the galvanized tub. (Courtesy of Dunkley Company.)

cherries and 75 pounds of sugar. The barrel is filled by adding alternately cherries and sugar so as to distribute the sugar throughout the pack. This may be facilitated by having a vertical chute, that leads from a hopper, located above the location of the barrel that is being packed. Two slide cutoffs constructed in the chute serve to regulate the volume

of sugar added to the pack. Each individual barrel must be filled to the designated weight.

When 30-pound containers are being filled, it is customary to place 25 pounds of pitted cherries in the container while it is on a scale. Sugar is then added to bring the net weight to 30 pounds. Some packers add approximately one-half of the cherries to the container, then add one-half of the sugar, which is followed by cherries to bring the net weight to $27\frac{1}{2}$ pounds, and finally sugar to make a net weight of 30 pounds. This method is more costly in labor but it provides for more satisfactory placement of the sugar than the former practice. An arrangement that provides for simultaneous adding of some sugar with the cherries, but permits a final layer of sugar on the top of the cherries, appears to be the most desirable practice.

Containers of other sizes that are to be filled with cherries and dry sugar are packed in the manner just described for the 30-pound container. One of the reasons why volume production of packs of consumer size of pitted red cherries and dry sugar has never attained importance is that no practical method has been developed that permits rapid handling such as is possible in canning in No. 2 cans. It is more convenient to use syrup rather than dry sugar when packing containers of consumer sizes.

Water expands about nine percent in volume on freezing and fruits also expand when frozen rapidly. Packers must allow for this expansion. Thus, the containers are filled to about 90% of their capacity when packed with either cherries and dry sugar or cherries and sugar syrup.

The use of parchment discs for both syrup and dry sugar packs to keep the fruit submerged is desirable. This helps in minimizing oxidation of fruit in the top of the container.

After the containers are filled to the required net weights with cherries and sugar or cherries and syrup, the covers are applied. This is a hand operation except for some containers of consumer size. A hand-operated press may be devised to force the friction covers to position, or a wooden mallet may be employed for such purpose.

4. Freezing Cherries

A. MICROBIAL ACTION

Microorganisms must be destroyed or inactivated in any method of food preservation. Temperatures employed in freezing preservation

destroy many of these organisms, but complete destruction is rarely attained even at extremely low temperatures. The microorganisms that remain alive are inactivated by low temperature and may resume growth if and when the temperature of the product is raised to levels of 15 to 20°F.⁷

The first objective in freezing is that of lowering the temperature of the product below 40°F. promptly to prevent spoilage by fermentation. This is just as important for products packed in large containers as it is for those packed in containers of consumer size. Numerous species of microorganisms have been observed to grow at temperatures considerably below 32°F. but the rate of growth becomes progressively lower as the temperature is reduced. Hence, the need for the secondary objective of prompt temperature reduction to levels that are below 15°F.

Ice formation results in increased concentration of the solutes and this concentration has a marked effect in reducing microbial growth. The mechanical and dehydrating effect of ice formation also kills some microorganisms.⁷

The microorganisms that remain alive after exposure to low temperature may cause rather rapid spoilage after defrosting because the freezing of the fruit destroys some of the plant tissues. This destruction of tissue may provide favorable conditions for the organisms to develop.⁷

B. RATE OF COOLING AND FREEZING

There are three intervals or stages of temperature changes in a fruit that is cooled from room or handling temperature to the usual holding temperature for frozen fruit. The first interval may be designated as the chilling stage; the second interval is the time required to pass through the freezing zone; and the third interval is that during which the temperature of the frozen product approaches that of the freezing medium.

Chilling the Fruit. During the first interval, the temperature of the product is lowered gradually to the level at which initial ice formation takes place. The lower limit of this interval is designated as the approximate freezing point of the product. The rate of cooling during this chilling period is affected by the proportion of sugar to fruit or the concentration of the syrup.

The size of container is of even greater importance in determining the rate of temperature reduction. Diehl *et al.*¹⁶ have shown that the

approximate time required to reduce the temperature of a 3 + 1 pack of berries in barrels to the approximate freezing zone is $3\frac{1}{2}$ days when the freezing medium is air at 0°F. Joslyn and Marsh¹⁷ report that a 3 + 1 pack of strawberries in No. 10 cans required seven hours to reach the freezing zone (about 27°F.) in a medium of still air at 2°F. A 5 + 1 pack of strawberries required an additional half hour. Since cherries have a lower specific heat value than berries, the time intervals should be somewhat shorter than those just cited.

Fruit in the center of a 50-gallon barrel may remain above 40°F. for over 36 hours. Thus, loss by fermentation occasionally occurs in fruits packed in such containers. The time required to lower the temperature of the product to less than 40°F. may be materially shortened by precooling the fruit or by packing it at the lowest practical temperature and placing the containers in the freezing room immediately after packing. Rolling the barrels once or twice each day for eight to ten days hastens the rate of temperature reduction by preventing the formation of a frozen layer about the outside of the product. This practice also serves other purposes; it prevents the same fruits from being exposed to the air for long periods and thus reduces oxidation, and it helps to maintain a uniform concentration of syrup throughout the barrel.¹⁶

The Freezing Zone. The time required to pass through the freezing zone, or the zone of maximum ice formation, usually is longer than that for the chilling. A 3 + 1 pack of strawberries in No. 10 cans passed through this zone in seven hours, but the time required for a 5 + 1 pack was $11\frac{1}{2}$ hours.¹⁷ Five days may be required for a 3 + 1 pack of berries in barrels to pass through this freezing zone when the air temperature is 0°F.¹⁶ A commercial packer observed that cherries packed in 30-pound tins were cooled to 25°F. in eight to ten hours in rooms maintained at 0 to -14°F. This fruit likely had passed through the zone of maximum ice formation.

The product remains at fairly constant temperature during the period of maximum ice formation. This is because some 125 to 130 B.T.U. (approximate latent heat of fusion of fruits) must be liberated from each pound of product to cause ice formation without actual change in temperature. There is, however, a slight lowering of temperature during the interval of ice formation. This may be explained by the fact that the freezing point of cherries averages about 27.8°F.,¹⁸ while that for sugar solutions varies with the concentration of the syrup. When the fruit is packed with dry sugar, the concentration

varies in different parts of the container. A 20% sugar solution has a freezing point of 29.5°F., and 85.6% of the solution is frozen at 20°F.; a 50% solution has a freezing point of 24.9°F. and only 53.8% of it is frozen at 20°F.¹⁹

Cooling in Sub-freezing Zone. In the third interval, the temperature of the product drops slowly to approximately that of the freezing medium. Some ice formation continues but the rate is much slower than that occurring during the period of maximum ice formation. The cooling rate for the frozen syrup decreases as the sugar concentration increases. Also, heat conductivity is slow during this period and the differential in temperature between the product and that of the air medium is small.⁷

Joslyn and Marsh¹⁷ report that the time required for strawberries packed 5 + 1 in No. 10 cans to pass from the end of the freezing zone to a temperature of 5°F. in a medium of still air at 2°F. was nearly as long as that required for both chilling and freezing. They also state that the total time required to cool a 30-pound, friction-top, tin can containing 40% syrup, to 5°F. in a freezing medium of still air at 2°F. was 65 hours. Only nine of the 65 hours were required to chill the syrup and take it through the zone of maximum ice formation, or to a temperature of 25°F.

C. THE FREEZING MEDIUM

Most of the cherries are frozen in special rooms, compartments, or tunnels for approximately 24 hours before they are transferred to storage rooms. These facilities usually are operated at temperatures of -10 to -20°F. and they generally are equipped with motor-driven fans that circulate the air through loose stacks of containers.

Air blast freezers, either of the short tunnel type or the more efficient progressive, cross-draft type, take advantage of the increased rate of freezing that is possible with high velocity of air movement. Doubling the air velocity increases the heat transfer coefficient 60% and reduces freezing time 27 to 40%.²⁰ However, doubling the air velocity requires eight times the amount of fan power. The most economical air velocity for freezing small packages and for tray or belt freezing is 650 lineal feet per minute.⁷ For larger containers air velocities as high as 2000 lineal feet per minute have been suggested. Much of the effectiveness of forced air circulation is lost unless care is taken to obtain uniform distribution over all exposed surfaces of the containers.

An air temperature of -10°F. provides about 18% faster initial cooling or chilling, 28% faster freezing, and 48% faster final cooling of the frozen product than air at 0°F. ²⁰ Thus, the greatest effect of temperature of the air is in the zone of maximum ice formation and in the subsequent final cooling.

Freezing in liquid media is not feasible for cherries that are packed in containers that are not liquid-tight. Freezing by direct immersion of individual cherries in a sugar syrup is not practical at present.

5. Storage of Frozen Pack

The recommended temperature range for permanent storage is 0 to -5°F. Fluctuating temperatures that cause defrosting and re-freezing should be avoided because they cause ice crystals to grow to such sizes that they may injure the texture of the cherries. Furthermore, they cause desiccation of fruit even though it is packed in tight containers. Moisture vapor may be transferred from the warmer surfaces of the product to the colder surface of the inner walls of the container where the moisture is deposited in the form of ice. Thus, the avoidance of fluctuating temperature probably is fully as important as the actual temperature level in maintaining quality in a frozen fruit.⁷

The temperature of the storage room should be maintained within a range of three or four degrees. Furthermore, the temperature of the refrigerating coils should not be more than five or six degrees lower than that of the storage room air. If a greater differential exists, moisture will condense on the coils and this moisture must, in turn, come from the stored product.

If the temperature of the cherries has not been lowered to the level of the storage room air prior to admission to the storage room, provision should be made for air circulation through the stacks of containers. This is accomplished by offset or staggered stacking of layers or tiers, and having spacing between rows of containers. On the other hand, if the temperature of the product is as low as that of the storage room, the containers may be stacked tightly to aid in preventing temperature fluctuations.

Liberal use of dunnage should be made in stacking the larger individual containers or the cases of small containers in freezer rooms. Dunnage, used to support the bottom layer and at intervals of two to

four layers, serves to keep the layers even, prevents stacks from falling, and provides for good air circulation through the stacks.

A space of at least four inches should exist between the walls of a storage room and the outer rows or stacks of containers or cases to provide for liberal circulation of air.

6. Transportation of Frozen Pack

Insulated refrigerated cars and trucks are used to transport frozen packs of cherries. Cars used for the transportation of frozen foods during the warmer portions of the year should have substantially more insulation in the walls, floor, and ceiling than those employed for transporting fresh fruits and vegetables. The cars should be precooled for 24 hours before they are loaded. This is accomplished by filling the end bunkers with coarse ice and salt or filling overhead bunkers with crushed ice and salt. The salt should make up 30% of the weight of the ice and salt mixture. An average air temperature of about 15°F. should be attained before loading is started. However, during the winter months, 20% salt should be sufficient. The use of dry ice to supplement the regular ice and salt has failed to lower appreciably the over-all temperature.⁷

The frozen cherries should be cooled to about -10°F. before they are loaded into the precooled cars. The use of a portable tunnel of Kapok or dry zero insulation which fits tightly at the storage door and at the car door will avoid considerable loss of refrigeration during the loading operation. The bunkers should be filled to capacity with ice and salt at all re-icing stations while en route to the destination.⁷

7. Frozen Puree

Cherries frozen in pureed form are preferred for ice cream, ice, jam, and general fountain use and may be used as a frozen dessert. The flavor and color are preserved in sieved or pulped fruits because oxidative deterioration can be minimized. Sugars exert their full protective effect and the full value of antioxidants, such as ascorbic acid, is obtained since both of these agents can be uniformly incorporated throughout the entire fruit mass.⁷

Only fully ripe fruits should be used for pulping. The cherries should be pitted before pulping. Exposure to air both during and after pulping should be avoided as much as possible. Flavor and color reten-

tion is better in a 4 + 1 pack, but the 5 + 1 and 6 + 1 packs are preferred by ice cream manufacturers. The addition of citric acid at the rate of 0.5% may improve palatability and keeping quality. If ascorbic acid is added, a rate of 0.02 to 0.03% by weight is recommended.⁷

The fruit pulp should be packed in containers that can be sealed hermetically. Surface oxidation may be avoided by closure under vacuum, by covering the surface with a sugar solution containing added antioxidant, or by placing a parchment paper disc, wetted with antioxidant, over the surface.⁷

Frozen puree desserts can be prepared by diluting the fruit puree with 67° Brix syrup sufficiently to provide the desired sweetness. The proportion of pulp to syrup should be 2 + 1 for Montmorency and 3 + 1 for Bing cherries.⁷

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BRINED CHERRIES AND THEIR PRODUCTS

Substantial quantities of cherries are preserved by brining. The brined fruits later are converted into maraschino cherries that are used in beverages, in canned fruit cocktails, in confections, in soda fountain preparations, in ice cream, and in the home for fruit salads, garnishes and various other purposes.

The processing of cherries by brining and the manufacture of products, such as maraschino cherries, from the brined cherries are in reality two distinct kinds of processing, though both operations are sometimes done in the same plants. Volume packing of brined cherries usually is accomplished in the areas where the cherries are grown. Manufacture of products from the brined fruit may be done in such areas or the brined cherries may be shipped to firms located in the larger cities that specialize in such manufacture.

1. The Brining Industry

Prior to the enactment of the United States Tariff Act of 1930, an average of about 7500 tons of cherries was imported annually. Some of the fruit may have been in the form of maraschino or glacé, dried or evaporated, or even fresh cherries, but it is thought that 80 to 85% of the imports were sulfured or in brine. Italy supplied 87% of the total imports in the period of 1926 to 1931 and all but about six percent of these were barreled cherries (brined). France contributed more than seven percent during this period, but these were mostly maraschino and glacé cherries. Other sources of imports included Yugoslavia and Albania.¹

The Tariff Act of 1930 established an import duty of 9½ cents per pound on all imports of pitted cherries in brine. The imports for the year 1930-31 amounted to less than 4000 tons and then dropped to an average of less than 1000 tons annually for the period of 1932 to

1939.² The effect on domestic production of brined cherries was essentially the reverse of the effect on imports. The 1925 output of brined cherries in the United States was 1925 tons; that for 1930 was 2470 tons; and that for 1939 was 21,150 tons.³ The quantity brined in the United States during the 10 years ending in 1951 averaged about 26,670 tons and ranged from 14,611 tons in 1943 to 41,430 tons in 1949.⁴

During the years 1947 to 1951, inclusive, the proportions of the total quantities packed by areas were as follows: California, 32%; Oregon, nearly 28%; Washington, 13%; and the Great Lakes States, 25%.⁴

2. Varieties for Brining

Practically all of the white or light-colored varieties of sweet cherries may be used for brining. The Napoleon variety is the leading one used for this purpose in the United States. Approximately two-thirds of the cherries brined in Oregon and Washington during the years 1940 to 1946, inclusive, were Napoleon and it is also the leading variety for brining in California. Bing probably ranks second to Napoleon in volume brined despite the fact that it is generally thought to be too large for such purpose. Other dark cherries used to some extent for brining in the Pacific Coast states include Lambert and Republican.⁵

Napoleon and Yellow Spanish are reported to be the best varieties for brining in New York.⁶ However, Montmorency is the variety brined to the greatest extent in eastern and midwestern states. Michigan packers brined approximately 36,000 and 45,000 barrels of red cherries in 1936 and 1937, respectively, and these were Montmorency except for a few tons of English Morello. Subsequent trends in Michigan have been toward larger proportions of sweet cherries. During the years 1942 to 1948, inclusive, slightly more than 60% of the brine pack was made from sweet varieties, including Napoleon, and the firmer-fleshed dark varieties. The pack in Wisconsin has been made entirely from red varieties.⁷

3. Harvesting and Handling Cherries for Brining

Sweet cherries that are to be packed in brine should be harvested when the juice of the fruits gives a Balling reading that is about two

degrees lower than that desirable for fresh shipment. An optimum Balling reading for the juice of Napoleon would be 16 to 20 degrees. The less mature cherries have less color than those that are fully ripe and are therefore more easily bleached. They also are firmer and are less susceptible to injuries that cause brown discolorations than are ripe cherries. On the other hand, the cherries should have reached a stage of maturity that will permit satisfactory pitting of the processed fruit.^{2,8}

The cherries should be picked and handled carefully to avoid bruising. The fruits are easily bruised before they are brined and any bruised spots remain brown after processing.

Cherries are usually picked with the stems for brining. Leaving the stems attached avoids injury and browning at the stem cavity. However, cherries may be picked without stems provided they can be placed in sulfur dioxide brine before there is time for browning of the injured stem cavity.⁹

Fruit picked during damp, cool weather should be allowed to stand for 12 hours in a dry place before brining to lower the turgidity enough to reduce cracking during the bleaching process.⁸

The cherries should move over a sorting belt prior to barreling to permit removal of cracked, bruised, scarred, and deformed fruits.⁸ Grading for size and further sorting for blemishes is usually done after the cherries have been in brine for several weeks or months, at which time the fruits are firm and may be handled more roughly.⁹

4. Brining and Bleaching

Solutions for Brining. The objectives in brining cherries are to bleach the fruits to a uniform white or yellowish white and make the fruits firm and rather tough. The bleaching and preserving agent is sulfur dioxide or sulfites and the hardening agent is lime or some salt of calcium. Alum has also been employed as an additional hardening agent, but, owing to its property of decreasing the hydrogen-ion concentration, it should be used with caution.⁹

Sulfur dioxide solutions generally are regarded as the most satisfactory bleaching agents. However, sodium bisulfite may be used successfully if a longer time is allowed for the curing. A solution containing 17 pounds of powdered sodium sulfite, six pounds of glacial acetic acid, seven pounds of calcium chloride in dry powdered form,

and possibly three pounds of alum to 100 gallons of water is suggested for brining Napoleon cherries in California.⁹

Sulfur may be burned in an enclosed system and the fumes of the burning sulfur may be absorbed in water to give the desired concentration. Lime is then added to the sulfur dioxide solution.¹⁰

When sulfur dioxide is used, the concentration may be varied between 0.7% and 1.5%. Cruess⁹ states that a solution containing 0.7% sulfur dioxide and 0.4% lime is often satisfactory for Napoleon cherries in California but he suggests that 1.0% sulfur dioxide and 0.6% lime is better for general use. Bullis and Wiegand^{2,8} say that 1 to 1.5% sulfur dioxide is usually satisfactory but that the latter is in general use in Oregon. They suggest that five pounds of hydrated lime or calcium carbonate be used for each 100 gallons of water where the sulfur dioxide concentration is to be 1.0% and that the lime be increased proportionately as the sulfur dioxide concentration is increased.

While fresh lime or calcium hydroxide is used rather generally in the preparation of the brine, Wiegand and Bullis² prefer the finer grades of calcium carbonate because the latter is easier to handle and because of the better possibility of getting a pure product.

Preparation of the Brine with Sulfur Dioxide. The supply of brine may be prepared in wooden vats or tanks that hold up to 1000 gallons. Locating these tanks on a floor above the room used for barreling permits feeding the solution by gravity to the barrels containing the cherries. The tanks should be fitted with brass, lead, or glass tubing that leads from the cylinders of sulfur dioxide to the bottom of the tanks where the tubing is coiled. The tubing should be perforated every 18 inches with holes that are $1/32$ to $1/16$ inch in diameter for the purpose of distributing the gas into the solution of lime or calcium carbonate. Wooden lids that will float on top of the solution in the tank will keep bubbles of gas from breaking the surface of the solution. The tank also should be equipped with a stirrer made of wood or other inert material.^{2,9}

Assuming that a 1.5% concentration of sulfur dioxide is desired in the brine, the following procedure is suggested for the preparation of 100 gallons of solution with lime: Make a smooth paste of $7\frac{1}{2}$ pounds of unslaked lime in 10 gallons of water in a tub. Add 90 gallons of water to the tank containing the coil. The lime paste is then added to the tank containing the water while the stirrer is in operation. The cylinder of sulfur dioxide is placed on a platform scale and 12.75 pounds of sulfur dioxide is admitted slowly through the tubing into the milk of lime. The stirrer is kept in operation to keep the milk of lime

in suspension. When all of the sulfur dioxide has been mixed with the lime, all of the latter should be dissolved, resulting in a clear solution.⁹

If the amount of sulfur dioxide is too high in proportion to the lime, the solution will be too acid and the cherries may develop skin cracks. If the reverse condition is attained, the solution will be neutral or alkaline in reaction and the cherries may soften, ferment and even putrify. It is therefore necessary to test the brine solution to make certain that the relationship between sulfur dioxide and lime is such that all the lime has been rendered soluble by conversion to a sulfite.⁹

Testing the Brine Solution. The brine solution may be tested for concentration of sulfur dioxide by titrating with a standard iodine solution. Cruess⁹ suggests the following procedure for the titration: Place 10 c.c. of the brine solution in 100 c.c. of water; add 5 c.c. of 1 : 3 sulfuric acid and a few drops of starch solution; titrate at once to a blue color with $n/10$ iodine solution. One cubic centimeter of $n/10$ iodine equals .0032 gram of sulfur dioxide; or a 10-c.c. sample is equivalent to .032 gram of sulfur dioxide per 100 c.c. (approximately 0.032% of sulfur dioxide). Thus, if 45.5 c.c. of $n/10$ is used for 10 c.c. of solution, then the percent of sulfur dioxide is 45.5 times 0.032, or 1.456%.

Barrels and Barreling. Paraffin-lined spruce, fir, or oak barrels of the best quality are in general usage for brining cherries. One head of a barrel is removed and the barrel is filled with 250 pounds of cherries that have just been delivered by the grower. The barrel is reheaded and all the hoops are tightened. Brine that previously has been tested for its concentration is then filled into the barrel through a hose inserted through the bung-hole. The bung is replaced tightly and the barrel is transferred to a cool warehouse.⁹

It is advisable to roll the barrels gently during the first few days that they are undergoing the curing process to mix the contents. Brine solution should also be added to replace that absorbed by the fruit. The storage warehouse should be kept cool until the cherries are well cured. Warm storage induces softening and discoloration of the cherries.⁹ If it is necessary to store the barrels out of doors, a sprinkling system may be employed to keep the barrels and their contents cool during the warmer portions of the day.

Curing usually requires a minimum of four to six weeks. The cherries may be held indefinitely, however, if the storage is cool and if the brine contains sufficient sulfur dioxide.

Cracking of Cherries during Brining. Cracking of cherries

while they are undergoing curing or are being held in brine is an indication that the sulfurous acid content is too high or that the hydrogen ion concentration is too low. Cruess¹¹ observed that no cracking occurred when the pH was 3.5 or higher. Wiegand and Bullis² likewise state that cracking of fruits is an indication that the sulfurous acid content is too strong and that the lime content is too low. They suggest increasing the lime content to prevent the trouble but warn that the product will spoil unless there is some free sulfurous acid present.

5. Stemming, Grading, and Fitting

After the cherries have been held in brine six weeks to six months, they usually are prepared for market. Stems may be removed at this time by mechanical stemmers. Those not separated from the fruits mechanically are removed by hand. The cherries are then graded for size over mechanical sizers that are equipped with stainless steel or slat-type screens. The cherries may also be sorted into two or three grades based on quality of the fruits.⁹

Pitting was formerly done with diminutive spoons designed for this specific purpose. This was a slow, tedious, and costly process. Maraschino pitters, similar to those used for pitting the fresh fruit, are now used. The plungers on these pitters are smaller than those used on fresh fruit pitters. The cherries must be placed in the pitting cups by hand because the pitting must be done in such a manner as to leave the blossom end of the fruit smooth.⁹

6. Leaching the Cherries

Barreled cherries usually contain in excess of 3000 p.p.m. sulfur dioxide. This sulfur dioxide must be reduced to less than 20 p.p.m. in cherries that are to be incorporated into canned fruit cocktails to prevent the sulfur dioxide from attacking tin plate and causing hydrogen swells. Some packers remove some of the sulfur dioxide and lime by placing the cherries in open barrels and allowing water, introduced at the bottom of the barrel, to flow slowly through the fruit for one or two days. This treatment must be regarded as supplementary to the following procedure and is not regarded as essential by all packers.

The cherries are placed in steam-jacketed copper or nickel kettles, or in wooden tanks equipped with steam coils, and are boiled, or brought to a boil, in four to six changes of water. The total boiling

time, or standing time after being brought to a boil, is about 15 minutes for each change of water. The number of such boilings is determined by the tenderness of the cherries and the sulfur dioxide content of the fruit. Methods for determining the sulfur dioxide content of the cherries are usually those described in the "Official and Tentative Methods of Agricultural Analysis" of the Association of Official Agricultural Chemists.⁹

The cherries may also be tested for sulfur dioxide by adding two or three drops of 2,6-dichlorophenol-indophenol to mixed fruits and observing the time of decoloration. If the blue color remains after one minute, the concentration of sulfur dioxide in the fruits is satisfactory.⁹

7. Dyeing the Fruits for Fruit Cocktail or Maraschino

Cherries that are to be used in fruit cocktails and salads must be dyed with an acid-fast dye that will not "bleed" and discolor other fruits. Erythrosine is the only satisfactory red food dye permitted for such purpose. Cherries that are to be prepared for use in beverage cocktails, desserts, and other household and restaurant use are dyed with Ponceau-3-R, a plain red dye. Amaranth is also permissible, but it gives a purplish-red color that is less desirable.

Only dyes that are certified by the Federal Food and Drug Administration may be used to color foods. The permissible dyes for cherries and their chemical names follow :

Erythrosine, F.D.&C. No. 1. Disodium salt of 1-pseudocumylazo-2-naphthol-3,6-disulfonic acid

Ponceau-3-R.-F.D.&C. No. 3. Disodium salt of 9-O-carboxyphol-6-hydroxy-2,4-5,7-tetraiodo-3-isoxanthone

Amaranth, F.D.&C. No. 2. Trisodium salt of 1-(4-sulfo-1-naphthylazo-2-naphthol-3,6-disulfonic acid

Dyeing with Erythrosine. Cruess⁹ and Weast¹² recommend the following procedure for dyeing cherries with erythrosine that have been pitted and halved and leached to the point where the 2,6-dichlorophenol-indophenol test indicates that the sulfur dioxide content is satisfactory :

Cover the cherries in a kettle with a solution made by adding 3.5 ounces of erythrosine and about four pounds of calcium carbonate to 100 gallons of water. Bring to a boil and maintain near the boiling point until the penetration

of the dye is complete. The cherries are removed from the dye solution and washed well in boiling water for two to five minutes to remove residual dye from the surface layer that might leach out later. The fruits are then rinsed in hot water and transferred to a 0.5% citric acid solution where they are held for about 15 minutes near the boiling point. This is followed by a rapid dip in cold water to remove the excess acid. The fruit is then ready for canning in syrups.

Bullis and Wiegand⁸ recommend one-half to one pound of baking soda, 0.75 to 1.25 pounds of citric acid, and 1.5 ounces of erythrosine dissolved in 12 gallons of water for 100 pounds of pitted and leached fruit. The amount of dye may be varied slightly to give the desired depth of color in the finished product.

These fruits may be finished to maraschino cherries by syruing and flavoring. The next step is to boil the fruits in a 20 to 30° Balling syrup that contains 1.5 ounces of citric acid per 100 pounds of syrup. This is repeated daily except that the density of the syrup is increased 4 to 5° Balling each day until a 40° Balling syrup is used. The cherries are then drained, rinsed in light syrup, packed in containers, and covered with syrup of approximately the same density as that of the final syrup used in the boiling treatment. Flavoring is then added and this is followed by sterilization. Discoloration will result if these cherries come in contact with iron.⁸

Atkinson and Strachan¹⁰ bring the cherries to a pH of 4.4 by leaching them in water at 140°F. in a tank before dyeing. They use 0.5 ounces of erythrosine dye for each 100 pounds of cherries that are designed for maraschino, or more for cherries that are to be used in canned fruit cocktails. The dye is dissolved in water and added to the cherries in a tank and the cherries are then heated to 140°F. for about 24 hours or until penetration is thorough. Citric acid is added to syrup that is placed on the fruit after dyeing is completed. The amount should be sufficient to bring the pH to 3.5.

Dyeing with Ponceau-3-R. Ponceau-3-R (certified food color) is used frequently for dyeing cherries that are to be packed in glass as whole fruits. It is not necessary to remove all of the sulfur dioxide in the leaching process if the fruits are to be packed in glass, but the leaching treatments previously described should precede the use of any dye.

Cruess⁹ recommends the addition of three ounces of ponceau-3-R dye, two pounds of 0.2% benzoate of soda, and 4.75 pounds of citric acid to each 100 gallons of 40° Balling syrup for California cherries. The cherries are boiled two to five minutes in this syrup and then set aside in agate dishpans overnight. The syrup is then removed and its density increased to 40° Balling. The cherries again are brought to a boil in the syrup, followed by standing overnight. Sugar is added again to bring the syrup to 40° Balling and then cherry flavoring is added to provide the desired taste. The cherries and syrup are then heated to 175°F., packed in hot glass, and sealed with vacuum or screw caps.

Benzoate of soda may be omitted if the cherries in the sealed jars are pasteurized at 180°F. for 30 minutes. Its purpose is to prevent spoilage after the

jar is opened. Citric acid is added to add flavor and to activate the benzoate of soda. After the processing procedure, the concentration of benzoate of soda will be about 0.1%.

Some cherries will shrivel if the original density of the syrup is as high as 40° Balling. Cruess suggests that 30° Balling syrup be used the first day, 35° syrup on the second day, and 40° syrup on the final day if shriveling occurs when the fresh syrup is at the 40° level.

Lee and Beavens³ developed a procedure for making naturally flavored maraschino-type cherries. The recommended steps for commercial procedure for each 100 pounds of bleached and pitted cherries that have been thoroughly leached are as follows: Cover the drained fruit with a one percent solution of citric acid and hold just below the boiling point for 15 minutes. The fruit then is heated to 190°F. in eight gallons of water to which has been added 25 pounds of sugar and 0.8 ounce of Ponceau-3-R. Allow to stand for 24 hours, and then add 25 pounds of sugar and heat to 190°F. After standing for 24 hours, add another 25 pounds of sugar and heat to 190°F. Let stand for 24 hours and then drain and pack the cherries in bottles. A naturally flavored, 65° Balling syrup, heated to 140°F., is used to fill the containers. This syrup should contain 0.1% benzoate of soda. The containers then are sealed and pasteurized at 180°F. for 20 minutes.

8. Maraschino Flavoring

Liqueur or cordial called "Maraschino" is a distilled product made from the small, black, sour fruits and young leaves of the *Marasca* cherry tree grown in Yugoslavia. The original maraschino cherries were *Marasca* fruits covered with the above liqueur. Increased demand for the product lead to the use of the liqueur with other varieties of cherries. Finally, an artificial maraschino flavor was developed that could be incorporated with a heavy sugar syrup. The flavoring material is usually a benzaldehyde, with or without other flavoring materials.³

Small operators may purchase artificial maraschino flavoring from supply houses. It can be prepared from a small amount of oil of neroli added to pure vanilla bean extract and pure authentic bitter almond oil dissolved in neutral, potable alcohol to provide about five percent of almond oil. The desired combination of these materials may be determined by experimentation. These essences are very powerful; too much may render the product unsalable.⁹

Lee and Beavens³ recommend that natural flavoring be attained by making the final syrup from a combination of Montmorency and English Morello cherry juices and sugar. Two combinations of several tried were preferred by panels of judges. One consisted of a 65° Balling

syrup made of eight parts hot-pressed Montmorency juice, two parts of hot-pressed English Morello juice, and sugar. The other syrup was of the same density but was made with nine parts of cold-pressed Montmorency juice and one part of cold-pressed English Morello juice. Directions for the preparation of these juices are presented in the next chapter.

9. Specialized Products

Various specialized products may be manufactured from brined cherries after the fruits have been leached. Among these products are such items as candied and glacé fruits, cordials, and confections. The preparation of these products is seldom done by manufacturers that can be regarded as a part of the cherry industry. Hence, they are not discussed in this book.

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CHERRY JUICE

Cherry juice has a pleasing flavor and an attractive color that appeals to many people. The juice and juice cocktails have become popular as beverages in a few markets that have had the benefit of publicity and sales promotion. Cherry juice is also used for the preparation of jelly, for marmalade bases, for wine making, and for the flavoring of many products.

1. Sources of Cherry Juice

The sweet varieties of cherries are too low in acid content and lacking in flavor to make a pleasing beverage juice unless they are blended with varieties of red cherries. Montmorency is the leading variety used for juice making and the product made from this variety is of good quality. Juice made from English Morello is preferred by most people to that made from any other single variety. It is darker red in color and stronger in flavor than that made from other commercial varieties. Early Richmond, on the other hand, makes a juice that is inferior to that of the other varieties mentioned.

The most satisfactory cherry juice is that made from a blend of varieties.¹⁻³ A blend of Montmorency and English Morello juices is superior in flavor, color, and aroma to that made from a single variety. When the price of sweet cherries is low enough to warrant converting them to juice, or when cracked cherries can be harvested and pressed before the fruits develop off-flavor or decay, such juice can be blended with that made from English Morello or both Montmorency and English Morello to make an excellent product.

Cherry juice designed for use as a beverage should be made from sound fruits that are well matured. The juice made from such fruits is full-flavored. Cherries that are too small for canning or freezing are satisfactory for conversion to beverage juice if the size deficiency is

not due to immaturity. Fruits that are removed from the sorting belts often are lacking in color and flavor because of immaturity; hence the juice made from them would be an inferior product. Cherries that have defects such as minor bruises caused by wind whipping and those that are cracked may be used for making a beverage juice, provided there is no decay or serious deterioration in flavor.

Some processors recover the juice resulting from the pitting operation. This juice usually is deficient in the constituents that are responsible for flavor and there is no way in which it can be improved except by mixing it with juice made from whole, sound, well-ripened fruits.⁴ Such a practice compromises the inferior and satisfactory juices and results in a mediocre product.

2. Expressing the Juice

Cherries that are to be utilized for the preparation of juice should be washed and soaked in the manner employed for handling cherries that are to be canned or frozen. Soaking in cold water chills the fruit and reduces fermentation and bacterial changes if the cherries must be held for several hours before they are prepared for processing. The soaking time, however, must not be long enough to leach out some of the valuable constituents of the fruits.⁴

There are three different procedures that may be followed in extracting the juice from the fruit. They may be designated as cold extraction, hot extraction, and post-freezing extraction. Cold extraction produces a juice that has a flavor more closely resembling that of fresh cherries than does hot extraction, and this juice is preferred by many people.^{1,4,5} The juice from hot extraction is brilliant red in the case of the Montmorency and Early Richmond varieties and is a very dark red when made from English Morello.¹ It coagulates or curdles the cell membrane and liquid contents, however, resulting in a sticky, mucilage-like material which is difficult to deal with in filtration and which has a slight musty flavor.⁴

Cherries that are frozen before the juice is expressed from them make a juice with a better flavor than that extracted by hot pressing. A high yield of bright-colored, naturally flavored juice, that is devoid of the pitty flavor characteristic of hot pressed juice, results.⁶

Cold Extraction. An apple grater may be employed to grind or cut the cherries into a coarse pulp for cold pressing or extraction. The knives on such a grater or grinder should be adjusted so that only a

few seeds are broken during grinding. Press cloths are used to build up layers of "cheeses" for extracting the juice with a hydraulic press in much the same manner as employed for expressing apple juice. The juice should be strained to remove pulp that may have worked its way through the press cloths during the pressing operation.^{1,4}

A continuous press that was designed especially for the extraction of juice from sugar beets is very satisfactory for use with cherries. It economizes on space and labor requirements and alters the cumbersome batch process to a continuous one. The juice may be fed onto a vibrating screen after it leaves the press, to remove pulpy material.

Cherries that have been frozen may be pressed without the usual operation of grinding, because the freezing will have broken down the cell structure sufficiently to permit the release of the color pigment.

Hot Extraction. Hot extraction of cherry juice may be accomplished by heating the washed fruits to 180°F. and then pressing the fruit in a rack and cloth hydraulic press similar to those employed for making apple juice.¹ Another method is to crush the washed cherries and then heat the crushed fruit to 150°F. before pressing.⁷ The latter temperature should be the more desirable for either procedure. The press cloths should be of fine weave to prevent the passage of too much pulp into the juice. The hot juice should be strained through a fine wire screen, preferably of the vibrating type, to remove coarse material expressed with the juice.

The yield of juice from Montmorency and English Morello cherries should be approximately 75% of the weight of the fresh fruit. Losses during subsequent filtration run 7 to 8%.³

3. Clarification and Filtration

Cherry juice is turbid after extraction because of the presence of small particles of pulp and other material in suspension. Filtration gives a product that has a brilliant eye appeal. However, many of the suspended particles are so small and colloidal in nature that they will pass through a fine filter unless they are flocculated or aggregated to form larger particles that can be caught in the filter medium. This process is called clarification. It may be accomplished by adding certain enzymes to the juice, by subjecting the juice to heat, or by a combination of heat and enzyme treatments.

Clarification of Cold-Pressed Juice. Juice extracted by cold-

pressing may be clarified by either the heat or the enzymic methods or by combinations of both methods. Heating juice made from red cherries to 190 to 200°F. immediately after extraction will inactivate enzymes, stop the action of certain microorganisms, and coagulate the suspended materials. The juice should be cooled promptly to precipitate the coagulated materials. The juice is then filtered.⁴

Juice extracted from sweet cherries by cold-pressing may be clarified adequately for subsequent filtration by adding one to two pounds of an enzyme carrier called Pectinol to each 100 gallons of juice and then allowing the juice to stand for 24 hours.⁸

Another recommendation is to heat the juice of red cherries to temperatures of 160 to 170°F. to throw down heat coaguable material, cool to 120°F., add approximately 0.1% Pectinol to the juice, allow to stand for three hours, heat to 180°F. to inactivate the added pectic enzyme, cool to room temperature, and then filter.¹

Clarification of Hot-Pressed Juice. Expressed hot juice should be cooled to 50°F. and then be allowed to settle overnight when the juice may be siphoned or drained off from the sludge and filtered.¹ Another recommendation is to heat the juice to 180°F. to coagulate the pectinous material, cool to 100°F. or lower, and then filter.⁷

Handling Equipment. Heat exchangers may be employed to heat and to cool the juice. The heating and cooling may be done in a continuous operation by using a double heat exchanger. Furthermore, the cool juice that is being conducted to the heating unit of the heat exchanger may be employed as at least a portion of the cooling medium in the second unit of the heat exchanger.

All equipment used for handling cherry juice should be corrosion resistant. The malic acid of the juice is very corrosive to both plain and galvanized iron. Stainless steel, aluminum, or glass-lined equipment is preferred, although copper or brass parts may be used provided the hot juice is in contact with them only momentarily. Wooden tanks may be used but they must be thoroughly scrubbed with hot water frequently.

Filtration. There are several types of filters that may be employed successfully for the filtration of cherry juice. One type consists of a series of corrosion resistant metal or wooden plates between which are placed canvas or other heavy cloths. Other types support the canvas cloths or bags on grooved baffle plates or on grids. Each cloth or bag acts as an independent filter, but all are fed from a common source of

juice and the filtrate from each cloth or bag is delivered to a common outlet. The cloths are designed to collect and build up a filter-cake composed of a filter-aid and the suspended materials of the juice that cannot pass through such a cake. The juice is forced through the filter by a centrifugal-type pump equipped with a by-pass that will permit regulation of the pressure applied to the unfiltered juice.

The filter-aid is infusorial or diatomaceous earth of medium grade. The first few minutes of operation should be designed to pre-coat the cloths of the filter with an even cake of filter-aid about one-fourth inches in thickness. This is accomplished by mixing one or more pounds of filter-aid in about ten gallons of cherry juice and, with the pump in operation, circulating this mixture through the filter until the filtrate becomes clear. A satisfactory filter cake will have been built when a sample of the filtrate collected in a glass cylinder, is clear and shows no evidences of particles of filter-aid (the latter will move downward in the juice while air will move upwards).

After the filter cloths are properly pre-coated, the course of the juice is changed from the precoating tank to a mixing tank. The latter contains juice to which filter aid has been added at the rate of four to five pounds per 100 gallons of juice. The clear filtrate is then collected in a suitable stainless steel or glass-lined tank.

The pump pressure should be maintained at low levels during precoating and during the early portion of the filtering process to permit development of a reasonably porous filter cake.

4. Sweetening, Diluting, and Blending

The juice made from commercial varieties of red cherries is too tart for the average taste. It must, therefore, be blended with juice made from sweet cherries or it must be sweetened by the addition of sugar or sugar syrup to make a product that appeals to the average palate.

Martin⁴ suggested adding enough sugar to red cherry juice to raise the soluble solids content to approximately 17%. Tressler¹ recommended diluting such juice with about one-half its volume of water and either adding sugar to bring the soluble solids content to that of the original juice (14 to 17° Brix) or sweetening to the degree desired by the prospective purchasers. Later suggestions were to dilute the juice with one-half to an equal volume of 15% sugar syrup² and to sweeten Montmorency juice with 7.5% sucrose.⁹

Blends of Montmorency and English Morello juices were found to be superior in flavor, aroma, and color to juice made from either variety alone. Furthermore, blends of cold-pressed and hot-pressed juices of these varieties were superior to juice made by either process.^{1,2,7} These blends are too tart and too strong in flavor to please most people; hence they should be diluted and sweetened. An excellent product resulted when the composition of the blend was approximately that shown in Table 24. This juice contained about 15% total solids.

TABLE 24. APPROXIMATE COMPOSITION OF A GOOD CHERRY COCKTAIL²

Kind of juice or syrup	Percent
Cold-pressed Montmorency	28.1
Hot-pressed Montmorency	9.4
Cold-pressed English Morello	9.4
Hot-pressed English Morello	3.1
15% sugar syrup	50.0

A demonstration sale of this product showed that 77% of the purchasers were pleased and had no criticism of the blend. Thirteen percent thought the product slightly weak, 4% thought it too strong, and 4% thought it too sweet.

Cherry juice that is either diluted and/or sweetened must carry a label on which such fact or facts are declared clearly. However, such a product may be called cherry cocktail or given some other trade name.

Apple-Cherry Blend. A very pleasing beverage may be made by blending juice made from varieties of red cherries with that made from apples. Such a product is regarded as better than that made from cherries alone. Furthermore, when apple juice is used as the diluent, the blended product may be labeled as fruit juice rather than as a cocktail.

When hot-pressed red cherry juice is used, two parts of it may be blended with one part of apple juice. Cold-pressed cherry juice should be blended with an equal amount of apple juice. If the cherries are fully ripened and have a high sugar content at the time of harvest it is unnecessary to sweeten the apple-cherry blend. More often it is advisable to sweeten the juice by adding approximately four ounces of sugar per gallon.¹⁰

5. Deaeration and Fortification

Deaeration of fruit juices prior to pasteurization is optional. Deaerated juices usually rate higher in brilliancy and in color, and are sometimes better in taste, after several months' storage than juices that have not been deaerated. Deaeration removes the oxygen from the juice and thus reduces deterioration due to oxidation during storage. On the other hand, deaeration may remove some of the volatile flavoring materials from the juice and also may result in some loss of volume through evaporation. These objections may be overcome largely by providing partial deaeration such as would result by operation at some 20 to 22 inches of vacuum.

Fortification of Montmorency juice with ascorbic acid gave an improved flavor after several months storage but the ascorbic acid had a deleterious effect on retention of red color.⁹

6. Preservation of Juice

Pasteurization. Cherry juice may be processed by either holding pasteurization or flash pasteurization. The former may be accomplished by heating the juice to 170°F. or slightly higher in a steam jacketed kettle and immediately filling cans or pre-heated bottles with such juice.¹⁻³

Flash pasteurization is more practical than holding pasteurization in plants that specialize in the packing of fruit juices. It economizes on labor, space, and essential equipment.

Tubular or plate-type heat exchangers may be employed for flash pasteurization and the same equipment may be used for heating and cooling the juice in some of the procedures for clarification of the juice. Heat exchangers employ steam or steam heated water as the heating medium. They usually permit raising the temperature of the juice from approximately room temperature to 170 to 175°F. in less than one minute. Heat exchangers should be equipped with accurate automatic temperature controls.

The juice that leaves the flash pasteurizer or heat exchanger should be delivered to can or bottle-filling equipment and the containers should be filled to provide a minimum of head space in order to provide a reasonably high vacuum when the juice is cooled. The containers are then hermetically sealed, and either inverted or placed on their sides to permit the hot juice to come into contact with the cover or cap

of the container. The containers need not be held in the inverted or horizontal positions for more than a few seconds in the case of undiluted juice, but if sugar or sugar syrup has been added to the juice, the holding time should be increased to as much as three minutes.¹ The containers of juice are then ready to be cooled.

Pasteurization at 170 to 175°F. kills the yeasts, but some of the mold spores and some of the more resistant bacteria remain alive. Mold spores that are not killed by this process are held in check by the oxygen deficiency, and the surviving bacteria cannot grow in the acid medium of the juice.

Other Methods of Preservation. Other methods of preservation of cherry juice, including freezing, germ-proof filtration, and chemical preservation, have not been employed extensively in the United States. In fact, it has been observed that the flavor of pasteurized red cherry juice is favored over raw juice preserved by freezing.⁹

7. Containers

Cherry juice packed in clear glass containers is a very attractive product and the glass permits consumer inspection of the displayed product. The crowns used with glass containers should be spot-lined to keep the juice from coming in contact with the cork.

Cherry juice is very corrosive and should not be packed in plain tin containers. Moreover, juice packed in plain tin is likely to become purplish in color shortly after it is packed. It is therefore necessary to use cans that are lined with special cherry enamel such as that used for the canning of the fruit.

8. Cooling the Pasteurized Juice

Cherry juice that has been subjected to either holding or flash pasteurization should be cooled after the sealed containers have undergone a short holding period. The cooling methods employed for canned cherries are suitable, or one may use the spinner coolers that are in common usage for rapid cooling of other processed fruit juices. Juice packed in tin containers should be cooled to approximately 100°F. and that packed in glass may be cooled to somewhat lower temperature. The higher temperature for tin containers is desirable from the standpoint of causing the external surfaces of the cans to dry rapidly.

The spinner coolers are designed to cause the containers to revolve in a horizontal position while the cans or bottles progress forward under sprays or in a bath of cold water. Obviously, glass bottles containing juice at approximately 170°F. must first be subjected to water at temperatures substantially higher than that of tap water to prevent breakage. The temperature of the initial water may be 90 to 100°F. After exposure for about two minutes to water of such temperature, the glass containers may be subjected to tap water.

9. Deterioration of Cherry Juice

Progressive changes in color intensity have been observed in cherry juice after packing and the rate of change seems to be associated with elevation of storage temperature. Spectrophotometer color analyses showed that the intensity of the red color was reduced somewhat even when the juice was held at 34°F. for six months. A storage temperature of 50°F. gave a very substantial decrease in red color which continued throughout the test period of ten months. Higher storage temperatures give more rapid reduction in red color. Yellow color, however, increased after three months in juices stored at 70°F. and after six months at 50°F.¹¹

The spectra at 400 to 420 $m\mu$ demonstrated the formation of a brown compound simultaneous with the decrease of the principal color at 500 to 530 $m\mu$. The spectra did not indicate that the brown color arises directly from the deteriorating principal color. It is believed that some of the brown color changes in fruit products are due to the so-called glucose-amino acid reaction, which may involve degradation of carbohydrates to furfural, or similar compounds, with subsequent condensations and polymerizations.¹¹

This chapter on fruit juice technology is purposely brief. Those desiring to read further on equipment and techniques are referred to the literature cited in this chapter and to books authored by Smock and Neubert,¹² and Tressler, Joslyn and Marsh¹³ and to a work edited by Jacobs.¹⁴

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DEHYDRATION OF CHERRIES

Only limited quantities of cherries have been preserved by sun drying or dehydration. This is partly because dehydration has not been able to compete economically with preservation by canning and freezing, and partly because the final reconstituted product lacks desirable quality. There is, however, justification for the dehydration of cherries under certain conditions. The dehydrated product economizes on storage and shipping space requirements and is therefore desirable for overseas shipment. It is preferred to cherries processed by other means for some kinds of utilization in the baking industry. Drying also serves as a method of utilizing sweet cherries that are split or cracked, bird-pecked, overripe, or damaged by rain.

Dehydrated sweet cherries are very satisfactory in taste and appearance and they are suitable for cooking. The red varieties may attain a slight raisin-like taste and they often reconstitute rather poorly.¹ This is because these varieties oxidize and turn brown on exposure to air, resulting in a reddish-brown, unattractive product unless special procedures are followed in preparing the fruits for drying.^{2,3}

Bing is regarded as the best of the sweet varieties for dehydration, and Black Tartarian is one of the poorest among those tested.¹ Other sweet varieties that have been dehydrated successfully in commercial quantities are Napoleon, Lambert, and Black Republican.^{1,2} The only red cherry that has been dehydrated on a commercial scale is the Montmorency.^{2,3}

Cherries may be dried as whole fruits, with or without stems, or as pitted fruits. If whole fruits with stems attached are dried, the stems are removed after dehydration by rubbing them off through hardware cloth. The cherries should be pitted if the product is to be used in pies and other baked products, in ice cream, or for the manufacture of preserves. It is not necessary to pit cherries that are to be

cooked for desserts after dehydration. While pitting reduces the amount of weight of the finished product, it adds to the cost of preparation, results in the loss of some juice, makes the product rather sticky, lowers the degree of reconstitution, and results in reduced tray loads.¹

Drying ratios for pitted sweet cherries were found to average about 4.2 to one, while those for whole fruits averaged about three to one, based on fresh fruit weights. These ratios vary with varieties; Bing dried to a ratio of 2.75 to 1 and Lambert to a ratio of 3.20 to 1.¹

1. Predehydration Treatments

Cherries that are to be dehydrated should be harvested when they have attained optimum or full ripeness as indicated by the soluble solids content of the expressed juice. They must be washed to free them of surface dust. Stemming generally is advisable for cherries that have been harvested with stems attached. If the cherries are to be pitted, they should be soaked in the manner employed for preparing cherries for canning. Subsequent treatments are designed to inactivate enzymes, to increase the rate of drying, to preserve color and flavor, and to improve the reconstitution of the fruits. Several procedures are outlined in the following paragraphs that are designed to accomplish one or more of these goals.

Blanching cherries in steam has given variable results.²⁻⁴ Wiegand *et al.*² favor spreading the pitted fruit on trays at a rate of three pounds per square foot, stacking the trays on cars, moving the cars into a cabinet where the cherries are steam blanched and where sulfur dioxide gas is later admitted from a cylinder. The cherries are held for one to two hours in the cabinet in an atmosphere containing the sulfur dioxide. They found that Montmorency absorbed sulfur dioxide less rapidly than other varieties with which they worked.

Alderman and Newcombe³ observed that holding pitted Montmorency cherries in water at 135 to 145°F. for three to four minutes gave a negative test for the enzyme peroxidase and gave the most satisfactory retention of color and texture of fruit. Temperatures above 155°F. resulted in the loss of soluble pigments and caused the cherries to become mushy and undesirable in texture. Better preservation of color and reconstitution of the cherries resulted, however, when wetting agents at 0.2% concentration in combination with one percent liquid pectin were incorporated in the water bath.

Following the above investigation, associates of these investigators dehydrated Montmorency cherries that had been immersed for three minutes in a solution of 1% 60-grade liquid pectin, 0.1% Tween 85, and 2% tartaric acid, maintained at 140 to 145°F. These cherries were regarded as satisfactory for short storage.⁵

Dipping sweet cherries in 0.5 to 2% solution of boiling sodium carbonate for 5 to 20 seconds, followed by a rinse in cool water, checked the skins of fruits sufficiently to prevent "case hardening" while the fruits were undergoing dehydration, and increased rate of drying. The concentration of sodium carbonate should be such as will result in the formation of extremely fine checks on the surface of the fruits. Fruits of Napoleon should be sulfured after the above treatment by exposing trays of the cherries to the fumes of burning flowers of sulfur (1.5 pounds to 1,000 pounds of fruit) for 15 to 30 minutes. These treatments gave a dehydrated product retaining one-third to one-half of the sulfur after drying and having good taste, good appearance, and good cooking qualities after reconstitution.¹

2. Sun Drying and Dehydration

Sun Drying. Dehydration is more desirable than drying in the sun for cherries, even in the interior valleys of California where sun drying has long been employed. The former is more rapid than sun drying and it can be controlled to provide a product of higher quality.¹

Either untreated or pre-treated cherries that are to be dried in the sun are spread on trays by hand and the trays are laid in rows on the ground in the drying yard. After the cherries become two-thirds to three-fourths dry, the trays are stacked in such a manner that air may pass freely between the trays. Drying then continues until the desired moisture content is attained.

Trays for Dehydraters. Most dehydraters are designed to accommodate cars or trucks, each of which carries a stack of some 24 to 28 trays to provide a combined height of the car and trays of about seven feet. The trays may be made of wood or a metal such as stainless steel or enameled metal. The wood trays have floors made of slats, with some spacing between them, and the metal trays have perforated floors to facilitate air circulation about the fruits. The trays are usually three by six feet in size. The cars, of the same dimensions, are designed to move into and through the dehydraters in a crosswise manner.

The rate of loading varies from 2 to 3.5 pounds of whole fruit per square foot of tray. Pitted fruit usually is loaded at a lower rate because the rate of drying is retarded if such fruit is more than one layer deep.¹

Dehydraters. There are many kinds of dehydraters in use but most of the cherries have been dried in the counter-current tunnel-type. Some cherries, however, are dried in cabinet dehydraters and evaporators, and in two-stage dehydraters. The tunnel-type dehydrater usually consists of one or more tunnels approximately 40 to 50 feet in length and having cross-sectional areas just large enough to allow cars carrying the loaded trays to move through them freely in a cross-wise position. There also is a smaller parallel tunnel located directly above or alongside the one that accommodates the loaded cars. The latter tunnel contains a source of heat and a motor-driven fan. There also must be provision for the regulation of the relative humidity by the admission of a controlled amount of fresh air into the air stream that is to be heated and provision for the exhaust of an equal amount of air after it has passed through the stacks of fruit. Thus, a portion of the air is recirculated through the heater and the stacks of fruit.

Temperature is controlled through regulation of the heater; velocity of air movement is controlled by the capacity of the fan, and relative humidity is controlled by adjusting the air intake and the exhaust.

The construction and operation of fruit dehydraters has been discussed in detail by Eidt,⁶ van Arsdell,⁷ Guillou,⁸ Perry *et al.*,⁹ and Bouyoucos and Marshall.¹⁰

Temperature and Humidity for Cherries. Napoleon cherries that had been dipped in boiling sodium carbonate were of better quality when dried in a counter-flow dehydrater about 11 hours with the entering air maintained at 140°F. and the air velocity at 500 feet per minute than when the drying time was eight hours with the entering air at 150 to 160°F. Little case-hardening developed when cherries that had been dipped in sodium carbonate were dried in air having a relative humidity as low as 10%. A relative humidity higher than 25% tended to cause discoloration of the fruit.¹

The drying time was observed to be 16 to 20 hours in a counter-current, single-stage, tunnel dehydrater when the dry bulb temperature of the entering air ranged from 145 to 150°F. and the wet bulb temperature was 90 to 94°F. This work was done with pitted cherries that were spread on trays at a rate of three pounds per square foot.²

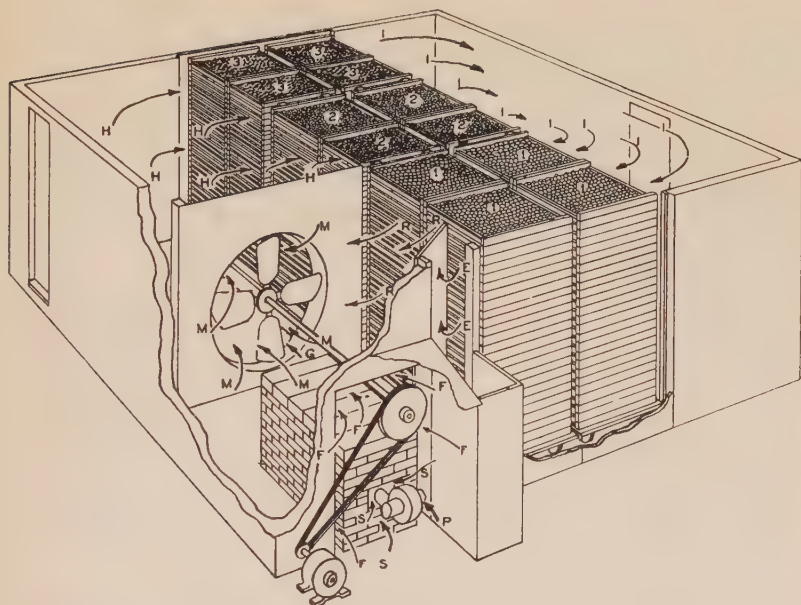


Figure 41. Cross-flow dehydrator, with axial-flow fan; designed by the University of California. 1, first position of fruit, when fresh; 2, second position of fruit, partially dried; 3, third position of fruit, nearly dried; *E*, exhaust air, escaping out of adjustable door; *F*, fresh air, entering beside furnace; *G*, gases heated in furnace; *H*, hot air delivered by fan to fruit in second and third positions; *I*, intermediate air passing from fruit in second and third positions to that in the first position; *M*, mixture of fresh air, gases heated in the furnace, and recirculating air entering the fan; *P*, primary fresh air for initiating combustion in the furnace; *R*, recirculated air passing from the fruit in the first position to the furnace chamber; *S*, secondary fresh air for completing combustion in the furnace.⁹

The moisture content of pitted Montmorency cherries was reduced to approximately 15% in 18 to 20 hours in a cabinet dehydrator with an initial temperature of 160 to 165°F. for five or six hours and then a gradual lowering of the temperature to 125 to 135°F. with an air velocity of approximately 600 feet per minute.¹¹

3. Packaging and Storing Dehydrated Cherries

Evacuating dehydrated cherries to 22 inches of mercury and then releasing the vacuum with sulfur dioxide gas from a cylinder for three

to five minutes to provide 2000 to 3000 p.p.m. of sulfur dioxide produced a product that remained brighter in color during storage than cherries not so treated. Blanching the dried fruit in steam for 30 to 60 seconds prior to gasing increased the rate of absorption of sulfur dioxide. However, the blanching treatment raised the moisture content of the fruit to 21.2 to 22.7%. Practically all the sulfur dioxide was found to disappear in 12 months of storage at room temperature or in three to four months at 95°F. That remaining disappears when the reconstituted fruit is cooked.²

Dehydrated cherries should be packed in containers that protect against insect infestation and the absorption of moisture. Cherries packed in fiber board containers absorbed up to 22% of their original weight during storage in a tropical cabinet maintained at 95°F. and a relative humidity of 75 to 85% while those packed in the better cellophane containers absorbed up to 4.6% of the original weight under these conditions. The best packaging material among those tested was a dorex thermoplastic wax, P-160, which resulted in no significant change in weight of the product during storage.²

4. Reconstitution of Dehydrated Cherries

The predehydration treatments were designed, at least in part, to improve the rehydration properties of both sweet and red cherries. Wiegand *et al.*² found that none of the cherries rehydrate completely. This is because the skin seems to toughen, making it difficult for the water to penetrate into the fruit. They suggest that the cherries be reconstituted by subjecting them to a temperature of 227°F. for five minutes or by a slow simmer for 30 minutes in water. A small amount of citric acid or lemon juice should be added to sweet cherries. Those that are to be used for preserves should be chopped and precooked to permit sugar to enter the fruits during reconstitution.

Alderman and Newcombe¹¹ noted that prolonged soaking of dehydrated Montmorency cherries tended to sacrifice color. The best of several treatments tried for rehydrating these cherries that were to be made into pies consisted of a 30-minute simmer in water at 175 to 180°F. Sugar should then be added at a rate of three parts of sugar to four parts of cherries and the sweetened cherries should be boiled for three minutes. The cherries are then ready for the addition of corn starch and the usual preparation for pie filling.

Those desiring to read further on equipment and techniques for dehydration are referred to the literature cited in this chapter and to books by Cruess¹² and Von Loesecke¹³ and a volume edited by Jacobs.¹⁴

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STANDARDS AND GRADES FOR CHERRIES

A number of standards and grades for both fresh and processed cherries have been established by federal and state agencies. Reproduction of all of them would necessitate much needless repetition. Furthermore, these standards are subject to occasional revision to meet changing conditions or situations. Therefore, only digests and partial reproductions of some of the standards and grades are presented.

Standards and grades are established by the federal department of agriculture and by some of the state or provincial departments of agriculture.

1. Cherries for Fresh Market**A. CALIFORNIA CODE FOR SWEET CHERRIES**

A digest of the Agricultural Code of California (1953) for sweet cherries that are packed for shipment to fresh fruit markets from that state follows:

Cherries shall be mature but not over-ripe, free from insect injury or bird pecks which have penetrated or damaged the flesh, unsealed skin breaks, mold, brown rot, decay and growth cracks, cracks or splits over $\frac{3}{8}$ inch in length even though well healed, except that well healed shoulder cracks shall be allowed regardless of length and serious damage due to sunburn, shriveling, sponginess, abnormal softening or other causes.

Not more than 10%, by count, of the cherries in any one container or bulk lot, may be below these requirements, but not to exceed one-half of this tolerance shall be allowed for any cause. In addition, 5% of the cherries may be slightly below the maturity requirements but in no case may such cherries show any green areas, excepting the Bing variety when testing not less than 16%, and the Tartarian variety when testing not less than 14% soluble solids.

The entire surface of all red and black varieties of cherries must have attained at least a solid light red color at the time of picking.

When cherries are packed in containers by the "face and fill" method, the average size of the cherries used in the fill shall not be smaller than would pack

one "row size" more than the cherries in the packed face; however, none of the cherries in the fill shall be of a size that would pack more than two sizes smaller. A tolerance of 10%, by count, is allowed in any one container.

Cherries shall be free from doubles except that a tolerance of 10%, by count, shall be allowed for doubles with both halves well developed, uniform in size and mature, and a tolerance of 2½%, by count, shall be allowed for doubles having one portion not well developed. However, any amount of such doubles shall be allowed if the container bears the designation "Exceeds Tolerance for Doubles" in letters at least ⅜ inch in height.

All containers of cherries shall bear upon them in plain sight and in plain letters on one outside end: The name and address of the packer, the name of the variety, and the number of rows of cherries packed or the minimum diameter of the cherries in the container expressed in inches or fractions thereof, in letters at least ⅜ inch in height.

When containers of loose cherries are marked with a row size designation at least 50% of the cherries shall be of a size no smaller than the row size number marked and none shall be more than two row sizes smaller than that marked on the container, except for a tolerance of 10%, by count. The row size number shall be deemed to be that number of cherries of uniform size whose aggregate width will equal 11½ inches.

When containers of loose cherries are marked with the minimum diameter of the cherries, not more than 10%, by count, of the cherries in any one container may be below the size marked, and the variation in diameter shall not exceed ¼ inch.

Cherries shall be in standard containers numbers 4, 10, 11, 12, 12A, 22C, 25 or 27. (See Chapter IX, Table 17.) Containers of other sizes may be used if marked on the outside of the end in letters not less than ½ inch in height, "Irregular Container."

B. UNITED STATES AND CANADIAN GRADES FOR SWEET CHERRIES

The United States standards for sweet cherries, issued June 2, 1927, provide for two grades: U. S. No. 1 GRADE and UNCLASSIFIED.

The U.S. No. 1 GRADE permits a 10% tolerance, by count, not more than one-half of which may be for defects causing serious damage, and not more than one-tenth of which may be for cherries affected with decay. Not more than 10% of the cherries in any lot may be below the declared size of the fruit. Size may be specified in terms of minimum diameter or the number of cherries to the pound. UNCLASSIFIED cherries are those not conforming to the specifications for U.S. No. 1 GRADE.

The Dominion of Canada Department of Agriculture (1951) has three grades for cherries as follows: SELECT GRADE, No. 1 GRADE, and No. 2 GRADE.

In addition to being sound and mature, cherries meeting the requirements of SELECT GRADE must be of superior size and color, while those in No. 1 GRADE must have good color and fair size. Any injury apparent at the time of grading and handling is not permitted in SELECT GRADE and No. 1 GRADE. The No. 2 GRADE permits slight handling and package bruises, skin breaks not involving an aggregate of more than $\frac{1}{8}$ inch in diameter, and hail marks not covering an aggregate of more than 25% of the surface. Total tolerances of 5% are allowed in SELECT GRADE and 10% for No. 1 GRADE and No. 2 GRADE, but not over 1% and 5%, respectively, are allowed for any one defect and not over 1% for decay.

2. Cherries for Processing

A. RED CHERRIES

United States grades for red sour (tart) cherries for manufacture, effective April 20, 1941, and reissued November 19, 1946, are essentially as follows:

U.S. No. 1 GRADE shall consist of sour cherries which are fairly well colored (1), free from decay, worms, pulled pits (2), attached stems (3), and free from damage (4) caused by bird pecks, hail marks, limbrubs, windwhips and other scars, sunscald, shriveling, foreign material, disease, insects, mechanical or other means. Unless otherwise specified, each cherry shall have a diameter (5) of not less than $\frac{5}{8}$ inch. A tolerance of not more than a total of 7%, by weight, of any lot of cherries may fail to meet the requirements of this grade, but not more than $\frac{5}{7}$ of this amount, or 5%, may fail to meet the grade requirements other than for attached stems, and no tolerance shall be allowed for worm-infested cherries.

U.S. No. 2 GRADE shall consist of sour cherries which meet all the requirements of U.S. No. 1 GRADE, except that a total tolerance of 12%, by weight, of any lot of cherries shall be permitted for grade defects, but not more than $\frac{5}{8}$ of this amount, or 10%, may fail to meet the grade requirements other than for attached stems, and no tolerance shall be allowed for worm-infested cherries.

UNCLASSIFIED shall consist of cherries which do not meet the requirements of either of the foregoing grades. The term is a designation to show that no definite grade has been applied to the lot.

(1) "Fairly well colored" means that the individual cherry has a decidedly pink or light red color predominating over the yellow on most of its surface.

(2) and (3) "Pulled pits" and "attached stems" are self-explanatory.

(4) "Damage" means any injury or defect which materially affects the appearance or processing quality of the cherry. Light-colored scars or scars which do not materially discolor the flesh beneath the skin shall not be considered damage.

(5) "Diameter" means the greatest crosswise dimension of the cherry.

B. SWEET CHERRIES

The United States grades for sweet cherries for canning or freezing, effective June 1, 1946, are similar to those for red (tart) cherries.

The principal differences are that not more than 1% of the U.S. No. 1 sweet cherries and not more than 2% of the U.S. No. 2 sweet cherries may be affected by decay and the cherries must also be free from doubles and damage caused by softness or shriveling. The minimum size must be specified and not more than 5% of the cherries, by count, may be below such size. Rain cracks or other skin breaks which exceed $\frac{1}{4}$ inch in length, and superficial scars, hail marks, windwhips, limbrubs, russeting, and similar scars affecting an area exceeding $\frac{3}{16}$ inch in diameter, or any scars which materially discolor the flesh are not permitted in the U.S. No. 1 GRADE.

U.S. No. 1 GRADE for sweet cherries for export for sulfur brining, effective May 28, 1940, and reissued February 28, 1946, is very similar to the description for that grade of red (tart) cherries for processing, except that there is no color requirement and a tolerance of 10%, by count, is permitted for defects and 10% for cherries below the specified size. Rain checks and other skin breaks may not exceed $\frac{1}{4}$ inch in length, and scars, including windwhips, limbrubs, and russeting, when light colored, must not cover more than 15% of the surface, or, when dark colored, must not exceed more than $\frac{1}{8}$ inch in diameter.

3. Processed Cherries

A. DEFINITIONS AND STANDARDS OF IDENTITY, QUALITY AND FILL OF CONTAINER

A digest of some of the provisions of the Federal Food, Drug, and Cosmetic Act that apply to canned cherries, as published June, 1951, is presented in the following paragraphs.

"Red Sour" or "Red Tart," "Light Sweet" or "Dark Sweet" are the words that must be used to designate canned cherries. The word "Pitted" must precede or follow the above designations if the cherries are pitted.

The packing media and the respective densities, as measured on the Brix hydrometer, 15 days or more after the cherries are canned, must be within the range prescribed in Table 25. "Water" includes any mixture of water and cherry juice, and "cherry juice" means fresh or canned expressed juice of mature cherries to which no water is added.

Packing Media Nos. 3 to 10, inclusive, of Table 25 are prepared with any one of the following: sugar; sugar and dextrose, provided the weight of the dextrose solids is not more than one-third of the sugar-dextrose combination; sugar and corn syrup, provided the weight of the solids of corn syrup is not more than one-fourth of the weight of the solids of the sugar-corn syrup combination; sugar, dextrose, and corn syrup, provided twice the weight of the dextrose solids plus three times the weight of the corn syrup solids does not exceed the

TABLE 25. PACKING MEDIA AND REQUIRED BRIX MEASUREMENTS FOR CANNED CHERRIES

Media	Brix Measurement	
	Sweet cherry	Red sour cherry
1. Water		
2. Cherry juice		
3. Slightly sweetened water	Less than 16°	Less than 18°
4. Light syrup	16-20°	18-23°
5. Heavy syrup	20-25°	22-28°
6. Extra heavy syrup	25-35°	28-45°
7. Slightly sweetened cherry juice	Less than 16°	Less than 18°
8. Light cherry juice syrup	16-20°	18-22°
9. Heavy cherry juice syrup	20-25°	22-28°
10. Extra heavy cherry juice syrup	25-35°	28-45°

weight of the solids of the sugar; except that packing media Nos. 7 to 10, inclusive, are not prepared with any invert sugar syrup or with any corn syrup other than dried corn syrup. If invert sugar syrup or corn syrup other than dried corn syrup are used in packing Nos. 7 to 10, inclusive, the liquid ingredient is considered to be water.

The label shall designate the packing media used and be preceded by "In" or "Packed in"; for example "Red Tart Montmorency Cherries in Light Syrup." The variety name is optional. If spice, flavoring, or a vinegar is added, the fact must be declared on the label; for example, "Flavoring Added."

Not more than 15%, by count, of the cherries may show blemishes such as scab, hail injury, discoloration, scar tissue, and similar abnormalities. A fruit showing skin discoloration shall not be considered as blemished if the aggregate does not exceed $\frac{3}{16}$ inch in diameter.

Not more than one pit is permissible in each 20 ounces of net contents of cans of pitted cherries. In the case of unpitted cherries, there must be no fruits weighing less than $\frac{1}{10}$ ounce and no fruits weighing more than twice that of the smallest cherry in the can. The weight of the pits in unpitted cherries must not exceed 12% of the drained weight of the cherries.

Pitted canned cherries shall be tested as follows to determine if they contain an excessive number of pits: Select at random enough cans to provide a minimum of 24 pounds of net contents. Open containers and weigh the contents. Count the pits. Count any piece of pit shell equal to or smaller than one-half pit shell as one-half pit, and any piece of pit shell larger than one-half pit as one pit, but, when two or more pieces of pit shell are within or attached to a single cherry, count such pieces as one-half pit if their combined size is equivalent to one-half pit shell or less, and as one pit if their combined size is equivalent to that of more than one-half pit shell. Calculate the number of pits present per 20 ounces of canned cherries.

The weight of pits in unpitted cherries is determined as follows: Empty the contents of a can onto a previously weighed circular sieve so as to distribute

the cherries evenly. An eight-inch sieve is used if the contents of the can is less than three pounds, or a 12-inch sieve is used for three or more pounds of contents. The bottom of the sieve must be No. 8 woven wire cloth. Without shifting the cherries, incline the sieve to facilitate drainage. Allow two minutes for draining and then obtain the drained weight. Pit the cherries, wash the pits free of adhering flesh, drain and weigh as described for the unpitted fruits. Determine the percent pits.

Canned cherries falling below the standards of the preceding four paragraphs must bear a label stating that the cherries are substandard quality or "Below Standard in Quality . . .," the blank space to be filled in with such words as "Partially Pitted," "Small," "Mixed Sizes," "Thin Fleshed," or "Blemished," as the case may be, and the word "Cherries" must immediately precede or follow the designation of quality.

The standard fill of container is the maximum quantity of the optional cherry ingredient that can be sealed in the container and processed without crushing the fruit.

B. GRADES FOR CANNED CHERRIES

Canners of cherries in the United States must meet the specifications for standards of identity, quality, and fill of container of the Federal Food, Drug, and Cosmetic Act. Designation of grade and the standards for grades of canned cherries are administered by the Agricultural Marketing Service of the U. S. Department of Agriculture.

TABLE 26. SCORE CHART FOR CANNED RED PITTED CHERRIES

Factors	Maximum points	GRADE A, FANCY	GRADE C, STANDARD	GRADE D, SUB-STANDARD
Color	20	17- 20	14-16 ^a	0-13 ^a
Absence of defects	40	34- 40	28-33 ^a	0-27 ^a
Character	40	34- 40	28-33 ^a	0-27 ^a
Total score	100	85-100	70-84	0-69

^a Cherries falling into this classification cannot earn a higher grade regardless of total score.

The standards administered by the two offices are not in conflict but there is some duplication of definitions.

Grades for Canned Red Cherries. A digest of the grades and definition of terms for canned red cherries, effective June 23, 1949, follow:

U.S. GRADE A or U.S. FANCY canned red sour (tart) pitted cherries possess similar varietal characteristics; possess a good, bright typical color; are practically free from defects; possess a good character; possess a normal flavor;

and score not less than 85 points (Table 26). In addition, not more than 5%, by count, of cherries can be less than $\frac{9}{16}$ inch in diameter.

U.S. GRADE C or U.S. STANDARD canned red sour (tart) pitted cherries possess similar varietal characteristics; possess a fairly good typical color; are fairly free from defects; possess a fairly good character; possess a normal flavor; and score not less than 70 points. There is no size requirement.

U.S. GRADE D or SUBSTANDARD canned red sour (tart) pitted cherries are those that fail to meet any requirement of U.S. GRADE C or U.S. STANDARD. Canned cherries of this grade, however, may be designated "U.S. GRADE D or SUBSTANDARD—Below Standard in Quality—Blemished" or "U.S. GRADE D or SUBSTANDARD—Below Standard in Quality—Partially Pitted" in accordance with the facts.

The designations for syrup densities are those presented in Table 25. The minimum drained weights are as follows: water pack, 11, $13\frac{1}{2}$ and 74 ounces, respectively, for No. 303, No. 2, and No. 10 cans; syrup pack, $10\frac{1}{4}$, $12\frac{3}{4}$, and $70\frac{1}{4}$ ounces, respectively, for No. 303, No. 2, and No. 10 cans.

Red cherries cannot make U.S. GRADE A (U.S. FANCY) unless they meet the size requirement. Otherwise, the grade is determined by the total score or by the score for any one of the following factors: color, absence of defects, and character. In other words, if the score for absence of defects is 27 points, the cherries must be designated U.S. GRADE D or OFF-GRADE, even though the total score might be 85 or more points (see Table 26).

Good, bright typical color (GRADE A or FANCY) means that the cherries possess a practically uniform color that is bright and typical of the color of canned red cherries that have been properly prepared and properly processed from ripe fruit. "Fairly good typical color" (U.S. GRADE C or U.S. STANDARD) means a fairly uniform typical color, which may range from a brownish cast to mottled shades of brown.

Absence of defects refers to the degree of freedom from harmless extraneous material, pits, mutilated cherries, and blemished cherries. Harmless extraneous material includes, but is not limited to, leaves or stems or portions of such. The definitions for pits are those of the standards of quality of the Food, Drug, and Cosmetic Act. A mutilated cherry is one that is so pitter-torn, or damaged by other means that the entire pit cavity is exposed and the appearance of the cherry is seriously affected.

Attainment of a score of 34 to 40 points for defects is possible provided that there is not more than one piece of harmless extraneous matter for each 60 ounces of net contents; that there is not more than one pit per 20 ounces of net contents; that not more than 10% of the cherries are mutilated and blemished; and that not more than 4% of all cherries are seriously blemished.

A score of 28 to 33 points for defects is possible if there is not more than one piece of extraneous material in each 20 ounces of net contents; not more than one pit in each 20 ounces of net contents; not more than 20% of the cherries are mutilated and blemished; and not more than 15% of the cherries are blemished. Cherries that fail to meet these minimum specifications for defects are U.S. GRADE D or SUBSTANDARD.

Character refers to the degree of maturity and the physical characteristics of the flesh. "Good character" (U.S. GRADE A or U.S. FANCY) means that the cherries possess a firm fleshy texture. "Fairly good character" (U.S. GRADE C or U.S. STANDARD) means that the cherries are not soft, tough, very thin-fleshed, or leathery, but possess a fairly firm or fairly fleshy texture.

Not more than one-sixth of the samples officially drawn for certification of grade of a specific lot may fail to meet all the requirements of the grade indicated by the average of the total scores or by the average grade of the scores for any one factor, and the scores of none of the samples may fall more than four points below the minimum score for the grade indicated by the average of the total scores.

Grades for Canned Sweet Cherries. The United States standards for grades of canned sweet cherries, effective May 15, 1953, for pitted or unpitted fruits, and the minimum scores for each (on the basis of 30 points for color, 20 points for uniformity of size, 30 points for absence of defects, and 20 points for character of fruit) are as follows:

U.S. GRADE A or U.S. FANCY, 90 points
U.S. GRADE B or U.S. CHOICE, 75 points
U.S. GRADE C or U.S. STANDARD, 60 points
SUBSTANDARD

There are no syrup cut-out requirements, but certificates of grade bear a notation in connection with the grade statement indicating the density of the syrup (see Table 25).

A score of 27 to 30 points (U.S. GRADE A or U.S. FANCY) may be given for cherries that are bright and possess a color typical of well-matured cherries. The background of light-colored varieties must be pinkish-yellow to pale-amber and the blush must be very light pinkish-tan to tannish-brown and the background of the dark varieties must be typical deep red to purple-red or purple-black. A rating of 24 to 26 points (U.S. GRADE B or U.S. CHOICE) may be given if the cherries possess a color typical of reasonably well-matured cherries. The basic background color of the light-colored varieties may be pinkish-yellow to amber and no more than slightly dull and the blush may range from tan to tannish-brown. The basic background color of the dark varieties is typical deep red to purple-red or purple-black which may be no more than slightly dull. A score of 21 to 23 points (U.S. GRADE C or U.S. STANDARD) may be given to cherries having a color typical of fairly well-matured fruits. The basic background color and blush of the light colored varieties may be variable or slightly dull but not off-color and that for dark varieties may be slightly dull deep red to slightly dull purple red or slightly dull purple-black but not off-color. Cherries failing to meet the foregoing requirements may be given 0 to 20 points (SUBSTANDARD).

Canned sweet cherries that are practically uniform in size may be given a score of 18 to 20 points. This means that no unpitted cherry weighs less than

$\frac{1}{10}$ ounce and that the largest cherry is not more than twice the weight of the smallest cherry and the largest pitted or unpitted cherry does not exceed the diameter of the smallest fruit by more than $\frac{3}{16}$ inch and that the maximum variation in size for 85% of the most uniform cherries does not exceed $\frac{1}{16}$ inch.

A score of 16 or 17 points may be given for cherries that are reasonably uniform in size. The minimum weight for each cherry and maximum range in size are the same as described in the preceding paragraph but the range in size permitted among 85% of the most uniform fruits is $\frac{1}{8}$ inch.

A score of 14 or 15 points may be given to sweet cherries that are fairly uniform in size. These cherries cannot be graded above U.S. GRADE B or U.S. CHOICE. These cherries may vary in size measurements provided no unpitted fruit weighs less than $\frac{1}{10}$ ounce and no fruit is more than twice as large as the smallest cherry. Cherries failing to meet the above requirements may score 0–13 points and shall not be graded above SUBSTANDARD.

Canned sweet cherries must attain a score of 27 to 30 points in absence of defects to qualify for U.S. GRADE A or U.S. FANCY. Such cherries contain not more than one piece of harmless extraneous material for 60 ounces of net contents, not more than one portion of cherry stem for each 20 ounces, not more than 1 pit for each 20 ounces of pitted cherries, and not more than 2% seriously blemished or not more than 5% damaged, misshapen, blemished cherries or more than a total of 10% slightly damaged, slightly misshapen or blemished cherries.

To attain a score of 24 to 26 points for defects, there must not be more than one piece of extraneous material in 40 ounces of contents, not more than five portions of stems for each 20 ounces of contents, not more than one pit in 20 ounces of pitted cherries and the tolerances for other defects mentioned in the preceding paragraph must not exceed 3%, 10% and 20%, respectively. Such cherries shall not grade higher than U.S. GRADE B or U.S. CHOICE.

Sweet cherries scoring 21 to 23 points for absence of defects shall not be graded above U.S. GRADE C or U.S. STANDARD. Tolerances cannot exceed one piece of extraneous matter, 10 portions of stems and one pit (for pitted cherries) in each 20 ounces of contents and not more than 15% of the fruits may be blemished or seriously blemished or not more than 30% of the cherries may be slightly damaged, misshapen or blemished.

To receive a rating of 18 to 20 points for character, the cherries must be thick-fleshed, tender but not soft or flabby and not more than 5% of unpitted cherries may have serious processing cracks. A credit of 16 or 17 points may be given cherries that are reasonably thick-fleshed, reasonably tender, but not more than slightly soft nor markedly flabby and, in case of pitted cherries, do not show more than 10% fruits with serious processing cracks. Such cherries cannot be graded above U.S. GRADE B or U.S. CHOICE. Sweet cherries that are variable in tenderness and texture, but do not run more than 10% markedly flabby fruits, and in which the weight of the pits does not exceed 12% of the drained weight of the fruits, may be given a score of 14 or 15 points. Such cherries shall not be graded above U.S. GRADE C or U.S. STANDARD. Cherries scoring 13 points or less in character shall not be graded above SUB-

STANDARD. This includes cherries in which the pits exceed 12% of the drained weight of the fruits.

The recommended minimum drained weights for sweet cherries packed in containers of various sizes are given in Table 27.

TABLE 27. RECOMMENDED MINIMUM DRAINED WEIGHTS, IN OUNCES, FOR PITTED AND UNPITTED CANNED SWEET CHERRIES

Container size or designation	In extra heavy syrups and in declared "dietetic packs" whether or not packed in water	In heavy syrups	In light syrup and in slightly sweetened water or juice	Other than declared "dietetic packs" packed in water
8Z Tall	4 ³ / ₄	5	5 ¹ / ₄	5 ¹ / ₄
No. 1 Tall	9 ³ / ₄	10	10 ¹ / ₄	10 ¹ / ₄
No. 303	9 ³ / ₄	10	10 ¹ / ₄	10 ¹ / ₄
No. 2	12	12 ¹ / ₂	12 ³ / ₄	12 ³ / ₄
No. 2 ¹ / ₂ Metal	17 ¹ / ₂	18	18 ¹ / ₂	18 ¹ / ₂
No. 2 ¹ / ₂ Glass	17 ¹ / ₄	17 ³ / ₄	18 ¹ / ₄	18 ¹ / ₄
No. 10	66	68	70	70

C. GRADES FOR FROZEN CHERRIES

Red Sour (Tart) Cherries. The score card for frozen red cherries that became effective June 18, 1949, is identical with that used for the canned product.

The grade is determined immediately after thawing to the extent that the cherries may be separated easily and the cherries free from ice and sugar.

A score of 17 to 20 points may be allowed for good red color, which means that the color of the fruit is bright and typical of properly ripened cherries and is so uniform that not to exceed 15% of the cherries may vary markedly from this color because of discoloration due to oxidation, improper processing, or other causes. Cherries of reasonably good color may receive a score of 14 to 16 points. Such cherries may not exceed 25% fruits that vary markedly from this color.

The definitions for absence of defects and character are essentially the same as those presented for canned pitted red cherries. Furthermore, the tolerances for certification of samples are the same as those for canned red cherries.

Sweet Cherries. The types of frozen sweet cherries are light sweet and dark sweet. The styles are pitted, unpitted, and unpitted and unstemmed. The grades and the minimum scores for each grade are: U.S. GRADE A or U.S. FANCY, 85 points; U.S. GRADE B or U.S. CHOICE, 70 points; U.S. GRADE D or SUBSTANDARD. The number of points that may be given each factor are: color, 30; uniformity of size and symmetry, 15; absence of defects, 30; character, 25.

A score of 30 points for color may be given when a marked variation from typical color does not exceed 2% ; a score of 29 for a variation of 2 to 4% ; 28 points for a variation of 4 to 6% ; 27 points for a variation of 6 to 8% ; 26 points for a variation of 8 to 10% ; 25 points for 10 to 13% variation ; 24 points for 13 to 16% variation ; 23 points for 16 to 18% variation ; 22 points for 18 to 20% variation ; 21 points or less for cherries that are definitely off in color. The minimum number of points for U.S. GRADE A is 26 points, and that for U.S. GRADE B is 22 points. Light-colored varieties that show no blush must meet the above requirements for U.S. GRADE A or U.S. FANCY classification, but there is no limit in variation of color for those light-colored varieties that do not make U.S. GRADE A or U.S. FANCY.

A score of 13 to 15 points may be given for size and symmetry if the minimum weight for each unpitted fruit is $\frac{1}{10}$ ounce or more, if there are no unseparated doubles, if not less than 95% of the cherries are well formed, if the diameter of the largest cherry does not exceed that of the smallest cherry by more than $\frac{1}{4}$ inch, and if 95% of the cherries do not vary more than $\frac{1}{8}$ inch in diameter. Such cherries classify in U.S. GRADE A or U.S. FANCY for this factor. A score of 10 to 12 points may be given unpitted cherries if the minimum weight of a cherry is not less than $\frac{1}{10}$ ounce, if there is present not over 10% unseparated doubles, if 85% of the fruits are well formed, and if 95% of the cherries do not vary more than $\frac{1}{4}$ inch in size. The foregoing cherries classify as U.S. GRADE B or U.S. CHOICE for this factor. Fruits not meeting the latter requirements must classify U.S. GRADE D or SUBSTANDARD for size and symmetry.

The definitions for absence of defects are essentially the same as those for canned red (tart) cherries except for the following: A surface discoloration that does not exceed $\frac{3}{16}$ inch and does not extend into the flesh is not considered a defect. Major defects include blemishes that extend into the tissue and deep cracks or checks in which the combined length and width exceeds $\frac{1}{2}$ inch. A score of 26 to 30 points may be given if there is not more than one pit for each 16 ounces of pitted cherries, if there are no stems or other extraneous material, if not more than 7% of the cherries are defective, including not more than 3% possessing major defects. Cherries scoring 22 to 25 points for defects classify as U.S. GRADE B or U.S. CHOICE and may not classify higher regardless of the total score for the product. Such cherries have not more than one pit per 16 ounces of unpitted fruit, have not more than one stem or other harmless extraneous material in each 16 ounces of fruit, and have not more than 15% defective cherries, including not more than 5% possessing major defects. Cherries failing to meet these requirements classify as U.S. GRADE D or SUBSTANDARD and may not classify higher regardless of the total score for the product.

Cherries that are practically uniform and of good character may be given a score of 20 to 25 points. Such cherries are thick-fleshed, firm, and well-ripened with not more than 5% of the fruits lacking in reasonable uniformity. A score of 16 to 19 points may be given for cherries slightly lacking in thickness of flesh and firmness, that are reasonably well-ripened, and have not more than 15% of overripe or immature fruits. Cherries failing to meet the latter require-

ments are classified as U.S. GRADE D or SUBSTANDARD and may not be scored above this grade regardless of the total score for the product.

D. GRADES FOR SULFURED CHERRIES

United States standards for grades of sulfured cherries prepared from sweet or red (tart) varieties in unstemmed and unpitted, stemmed and unpitted, or stemmed and pitted styles became effective June 12, 1951.

These cherries are packed "with or without the addition of a hardening agent, in a solution of sulfur dioxide of sufficient strength to preserve the product." The number of points that may be given to each factor are: color, 20 points; absence of defects, 40 points; and character, 40 points. The grades are U.S. GRADE A or U.S. FANCY, U.S. GRADE B or U.S. CHOICE, U.S. GRADE D or SECONDS, and U.S. COMBINATION GRADE.

Cherries must possess a practically uniform color typical of well-bleached sulfured cherries to attain a score of 17 to 20 points. Sulfured cherries possessing reasonably uniform color may score 14 to 16 points and may not be graded above U.S. GRADE B or U.S. CHOICE. Cherries failing to score more than 14 points for color must not be graded above U.S. GRADE D or SECONDS.

Sulfured cherries that are practically free from defects may be given a score of 34 to 40 points. This means that not more than a total of 10%, by weight, of the cherries are misshapen, damaged by mechanical injury, seriously damaged by mechanical injury, blemished or seriously blemished of which not more than 5%, by weight, of all cherries are misshapen, seriously damaged by mechanical injury or seriously blemished. Cherries reasonably free from defects may score 28 to 33 points. Not more than 10% of such cherries may be misshapen, seriously damaged or seriously blemished. These cherries shall not be graded higher than U.S. GRADE B or U.S. CHOICE. Cherries that fail to score 28 or more points cannot be graded higher than U.S. GRADE D or SECONDS.

Damage by mechanical injury refers to pitter tears that materially affect the appearance, and any open pitter holes aggregating $\frac{1}{8}$ to $\frac{3}{16}$ inches across. Cherries are considered seriously damaged by mechanical injury if pitter tears seriously affect the appearance or if open pitter holes aggregating more than $\frac{3}{16}$ inches are present. Blemished cherries may have dark surface discolorations not exceeding $\frac{3}{16}$ inches in diameter or $\frac{1}{8}$ of the surface of the fruit or they may be cherries having light surface discolorations aggregating $\frac{1}{8}$ to $\frac{1}{2}$ of the surface of the fruit. Rain checks in the stem basin $\frac{1}{4}$ to $\frac{1}{2}$ inches long or outside the stem basin and $\frac{3}{16}$ to $\frac{3}{8}$ inches long are also considered as blemishes. Seriously blemished cherries may have dark surface discolorations covering $\frac{1}{4}$ or more of the surface of the fruit or light surface discolorations exceeding $\frac{1}{2}$ of the surface area of the cherry. Rain checks more than $\frac{1}{2}$ inch long in the stem basin or more than $\frac{3}{16}$ inch long outside the stem basin are considered serious blemishes.

Sulfured cherries of good character (score 34 to 40 points) possess a firm,

fleshy texture, retain their approximate original shape, are not shriveled or watery, and do not show more than slight collapsed areas of flesh. A tolerance of not more than 5%, by weight, is permitted. To score 28 to 33 points, the cherries must have reasonably good character. They must be reasonably firm and may have slightly lost their original shape, and may be slightly shriveled and show moderate collapsed flesh. A tolerance of 10% is permitted. Such cherries shall not be graded above U.S. GRADE B or U.S. CHOICE. Cherries failing to meet any of the above requirements may score 0 to 27 points and shall not be graded above U.S. GRADE D or SECONDS.

If 80%, by weight, of the cherries meet the requirements for U.S. GRADE B or U.S. CHOICE and 35% meet the requirements for U.S. GRADE A or U.S. FANCY, the cherries may be graded U.S. COMBINATION GRADE.

In addition to the above grade requirements, not more than $\frac{1}{8}$ of the samples drawn may fail to meet the grade requirements and none of the samples may fall more than 4 points below the minimum score for the grade indicated by the average of the total scores.

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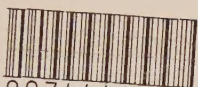
Zinc, deficiency in trees, 93
in fruits, 128

68

634.23 M36C



a39001



007444444b

4.23

M36c

61

72-1

73-1

